

TETRODON POISONING

BY WARREN HAROLD YUDKIN*

Bingham Oceanographic Laboratory, Yale University

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ABSTRACT

The common puffer, *Spheroides maculatus*, has recently attained market status as a result of the increased utilization of "trash" fish. However, it belongs to the Tetraodontidae, many of whose members are notably toxic. This paper summarizes the pertinent information on tetrodon poisoning (History and Distribution, Toxicity and Chemistry, Action and Symptoms, etc.); in so doing it provides evidence that the toxic substances of many Tetraodontidae are located chiefly in the gonads and liver and may vary quantitatively with the degree of maturation. It also indicates the expediency of seasonal and other toxicity tests on *S. maculatus* and of special care in its preparation for market until it has been more thoroughly investigated.

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INTRODUCTION

During the past year the efforts of a number of individuals and organizations have been directed toward the increased utilization of marine resources. That work along these lines should be intensified under emergency conditions is in no way surprising. On the other hand, it is an unfortunate commentary that there should be such a multiplicity of unsolved problems in this field. Considering only the species which are discarded from the commercial catch as "trash," but which are in reality potential sources of food for human or other consumption, it is common knowledge that the wastage is of great magnitude. Yet adequate figures on seasonal composition in many different fisheries are not available. And the inadequacy of the available information on "trash" fish is further evidenced by the fact that there is not even unanimity of opinion as to which of these forms should be utilized.

Among the "trash" species which have been recommended lately as food fish is the common puffer, *Spheroides maculatus* (Bloch and Schneider), of the Atlantic coast. This fish is abundant and is taken in large quantities in certain seasons by trap-net and other fisheries. It has been eaten in various local communities for many years, and is generally recommended as having an exceptionally good flavor. The fish has not had market status until recently, mainly because there was an insufficient demand for it and also because the percentage of the total weight that can be recovered as the edible portion is relatively small. But at the present time the puffer appears on the market in limited quantities, both fresh and frozen.

However, *Spheroides maculatus* belongs to the family Tetraodontidae, many of whose members are notably toxic.¹ Thus a number of

¹Jordan (1925) states that "poisonous alkaloids are developed in the flesh" throughout the Plectognaths as a whole. Among those specifically mentioned as being toxic are some of the Balistids, Ostraciids, Tetraodontids, and Diodontids. The members of the latter two families have many popular names, a number of which are common to individuals in both groups. This fact, in conjunction with the wide variation in scientific terminology, leads to frequent confusion. Some of the names applied to the Tetraodontidae and their close relatives follow: swellfish, swellbelly, swelltoad, blowfish, pufferfish, globe fish, porcupine fish, balloon fish, toadfish, blaser (in the Dutch East Indies), fugu (in Japan), Ikan buntal (in Malaya), tambores (in Cuba), botete (in the Philippines), etc. In the present paper "tetraodon" is used in a general sense, except where authors quoted do otherwise or in dealing with those references in which the specific identity of the fish involved is clear.

people die of tetrodon poisoning each year in Japan. For example, Nagai and Ito (1939) say, "The ovary of the Fugu fish (*Spheroides*) contains a strong poison, about 20 people a year becoming its victims." The poisoning also assumes serious aspects in the West Indies, East Indies, Malaya, the Philippine Islands, and the Cape of Good Hope, according to various authors. In view of the close relationship of *S. maculatus* to these toxic species, it seems appropriate to examine the literature on tetrodon poisoning for evidence as to whether or not special care need be exercised in utilization of this form, and also as to the advisability of testing it for possible toxic effects.

That this fish has been eaten for some time in various regions with few if any definite reports of ill effects is a clear indication that its flesh is not ordinarily toxic. This does not prove, however, that it might not be poisonous under certain circumstances. In this connection several possibilities immediately present themselves. Thus it is not inconceivable that Dinoflagellates, only occasionally appearing in sufficient abundance to be effective, might impart toxic qualities to the flesh (Nigrelli, 1936). Much more probably, a toxic substance might be located in the viscera and might result in poisoning only when the fish are improperly cleaned, or when they remain ungutted for some time after their capture so that the poison has an opportunity to permeate the muscle. With regard to the latter alternative, there is also the possibility that the toxic substance might be seasonal in its appearance or concentration—*i. e.*, it might, for example, be associated with the maturation of the gonads and therefore would manifest itself only before and during the spawning time. It is hoped that the summary of the available information on tetrodon poisoning which is presented here will indicate the need for research which will result in one of the following alternatives: the complete vindication of *Spheroides maculatus*, recommendations for special care in its preparation for market sale, or its condemnation as a species which can be utilized with reasonable safety. Such research is at present in progress in the Bingham Oceanographic Laboratory, but should unquestionably be undertaken by other workers in different localities if the answers to this problem are to be in any way complete.—D. M.

HISTORY AND DISTRIBUTION

There is record of the poisonous qualities of the blowfish of the family Tetraodontidae as early as 1690, for Engelbert Kaempfer, in his exhaustive history of Japan describes in some detail the early Japanese customs surrounding the eating of the fish. Evidently it had considerable notoriety throughout the islands.

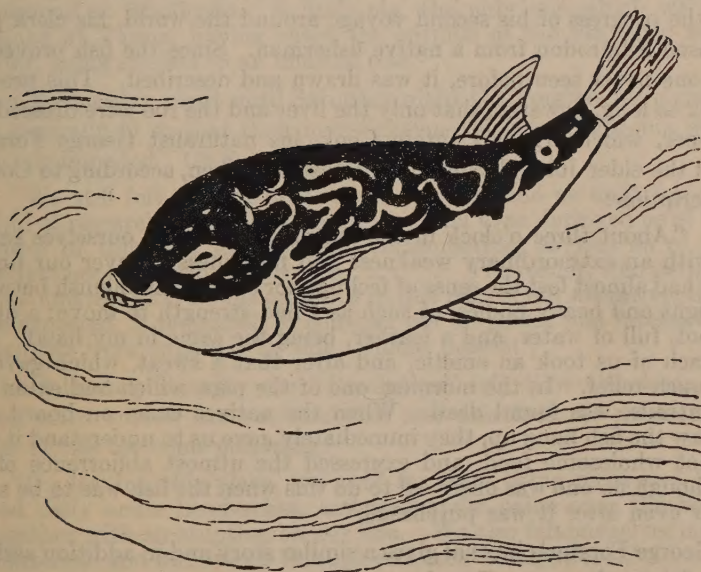
"Furube is another Fish, not very large. The Dutch call him Blazer, which signifys Blower, because he can blow and swell himself up into the form of a round Ball. He is rank'd among the poisonous Fish, and if eat whole, is said unavoidably to occasion death . . . This the Japanese reckon a very delicate Fish, and they are very fond of it. But the Head, Guts, bones, and all the garbage must be thrown away, and the Flesh carefully wash'd and clean'd before it is fit to eat. And yet many people die of it, for want, as they say, of thoroughly washing and cleaning it . . . And yet the Japanese won't deprive themselves of a dish so delicate in their opinion, for all they have so many Instances, of how fatal and dangerous a consequence it is to eat it."

Thus, from early times the tetrodon was considered poisonous by the Japanese, yet the important fact remains that the fish was eaten at least as early as the 17th century, provided all the viscera were removed and the remaining flesh carefully washed. Kaempfer also states that "it is sold much dearer than common Fish, and not eat, but when fresh." This suggests that the toxic qualities of the tetrodon lie in the viscera, and that the fish must be carefully washed to remove any poison left after the fish has been eviscerated. It also leads to the suspicion that the fish cannot be allowed to remain ungutted too long before being eaten, presumably because the poison from the viscera permeates the tasty skeletal muscle.

Kaempfer further informs us that, "Soldiers only and military men, are by special command of the Emperor forbid to eat this fish. If any one dies of it, his son forfeits the succession to his father's post, which otherwise he would have been entitled to." The above rules were made in order to decrease the number of suicides that were accomplished by eating "Furube," or "Fugu," as the Nipponese now call it. This is further emphasized by mention of another kind of tetrodon, different from that previously mentioned because "the poison of this sort is absolutely mortal, no washing nor cleaning will take it off. It is therefore never ask'd for, but by those who intend to make away with themselves."

河豚
The fugu.

Fig 2.



The fugu (or furube) as pictured in Kaempfer's *History of Japan*, 1728. This is probably the earliest representation of this toxic fish to appear in occidental literature.

Osbeck makes mention of the toxic qualities of the tetrodon as the Chinese know it in his *Voyage to China and the East Indies* in 1771:

"Kay-po-oy, *Diodon ocellatus* (*Tetrodon ocellatus* Linn.) is one of the finest fish I ever saw, but so poisonous that whoever eats of it generally dies in two hours time. The Chinese, who affirmed the fact, seeing me take the fish into my hands, earnestly desired me to wash myself, adding that it is forbidden under some great penalty, to be sold among other fish."

He then goes on to describe the fish in detail and states that it was taken at Canton and a "civil sailor, who was present when the Chinese caught it, gave it to me."

Tetrodon poisoning appears in the literature again several years later (Cook, 1777; Forster, 1777 and 1778). On Wednesday afternoon, September 7, 1774, when Captain Cook was at New Caledonia in the progress of his second voyage around the world, his clerk purchased a tetrodon from a native fisherman. Since the fish proved to be one never seen before, it was drawn and described. This process took so long, however, that only the liver and the roe were dressed for supper, which organs Captain Cook, his naturalist George Forster, and the elder John Forster, merely tasted. Then, according to Cook's description:

"About three o'clock in the morning, we found ourselves seized with an extraordinary weakness and numbness all over our limbs. I had almost lost the sense of feeling; nor could I distinguish between light and heavy bodies, of such as I had strength to move; a quart pot, full of water, and a feather, being the same in my hand. We each of us took an emetic, and after that a sweat, which gave us much relief. In the morning, one of the pigs, which had eaten the entrails, was found dead. When the natives came on board and saw the fish hang up, they immediately gave us to understand it was not wholesome food, and expressed the utmost abhorrence of it; though no one was observed to do this when the fish was to be sold, or even after it was purchased."

George Forster's journal gives a similar story and in addition assigns the fish to the genus *Tetrodon*:

"It was of the genus, by Linnaeus named *tetraodon*, of which several species are reckoned poisonous. We hinted this circumstance to captain Cook, especially as the ugly shape, and large head of the fish, were greatly in its disfavor; but he told us he had eaten this identical sort of fish on the coast of New Holland, during his former voyage, without the least bad consequences. At supper

the liver of this fish was served up, which was very large and oily. For this reason the captain, my father, and myself eat only a morsel or two of it, and thought it had no other bad taste, than what arose from the oil."

The description of the effects of the poison is much the same as that given by Cook but goes into more detail:

" . . . the blood had left our cheeks, all our limbs were benumbed, and without sensation, and a great degree of languor and oppression had taken place. Emetics were administered, which gave my father and myself some relief, but had not much effect upon captain Cook. We took a sudorific after this, and went to bed again . . . The poison which had been thus fatal to us, had likewise affected several dogs, taken on board at the Society Islands; these creatures having seized upon the remains of the liver, were extremely ill, and had the same symptoms as those which were poisoned at Mallicollo. A little pig, the only one which we obtained at Tanna, having eaten the entrails of the fish, died soon after, being swelled to an unusual size."

From Wednesday night until Saturday night the Forsters were giddy and generally ill so that their investigations on New Caledonia were seriously impeded. On Saturday Forster writes:

"We still felt returns of dizziness which made us unfit for any kind of researches, in spite of ourselves, and even deprived us of the power of thinking, judging, and remembering, as well as of the perfect use of our external senses . . . The reader, who perhaps may find less food for his curiosity in this part of our narrative, than he expected, is requested to consider our corporeal and intellectual faculties were impaired by this virulent poison."

The following Tuesday the "Resolution" left New Caledonia, at which point Forster sums up the visit and describes the subsequent effect of the tetrodon poisoning:

"On leaving this place, we were far from being recovered, but had daily acute head-aches, and spasmodic pains over the body, together with an eruption on our lips. We also felt ourselves much weakened, and unfit to go through our usual occupations."

From the foregoing accounts of this episode it seems reasonably certain that a virulent and concentrated poison, which manifests itself by disturbing the nervous system, resides in the liver, ovaries, or both, in the species in question. The fish was definitely of the genus *Tetrodon* Linn., and John Forster in his "Observations" on the same voyage indicated that it was related to *Tetrodon ocellatus*.

The first important investigation carried out in regard to the tetrodon poison was done by Geerts on the request of the Japanese government. His work was published together with other observations on fugu poisoning by Remy in 1883, and has served as a good foundation for most subsequent studies on the tetrodon poison.

Remy lists the common poisonous species as follows: *Tetrodon pardalis*, *T. rubripes*, *T. lineatus*, *T. vermicularis*, and *T. rivulatus*. Then, following the experimental feeding of cats and dogs and after inspection of case histories, he reaches two salient conclusions:

"In the toxic fugus, the poison lies exclusively in the genital organs, principally the ovaries, and the toxic influence of the fish is proportional to the development of its genital organs.

"The poison of the genital organs of the Tetrodons is a poison paralysing the nervous centers which has a more or less strong effect on the general and special sensibilities, and on the motility, and effects death by paralysis of the heart and suffocation."

The case histories upon which Remy was able to draw were published in France and have been unavailable to this author.

That tetrodon poisoning was not uncommon at the Cape of Good Hope is evident from Pappe (1866) who describes the situation in his *Synopsis of the Edible Fishes at the Cape of Good Hope*:

"The highly poisonous nature of this small fish [*Tetrodon Honkenyi*] has been long known to the fishermen of the Colony, yet several persons have fallen a sacrifice from using it as food . . . in August 1845, two seamen belonging either to the Banka or Postillion, met with an untimely death, from having partaken of this fish, while the same fatal result, in August 1846, occurred to one of the crew of the French corvette *L'Oise*, who died on board of that vessel from the very same cause."

Since, at that time, no work had yet been done on the poison, Pappe makes some speculations as to the nature of the poison:

"The exact nature of the poison has as yet been but little ascertained. It has been ascribed by some to the feeding of the fish on poisonous mollusca, by some to the disengagement of sulphuretted hydrogen, and by others again to a particular specific venom not yet discovered by chemical analysis. Whether the fish possesses that poisonous quality at all seasons, is not sufficiently known but it seems that most species belonging to the tribe are equally noxious. . . ."

Parts of the Pacific to which tetrodon poisoning is common besides China and Japan are Indo-China, Malaya, the Dutch East Indies,

and the Philippines. The common poisonous Philippine species, according to Seale (1912), is *Spheroides sceleratus*, locally called "tinga-tinga" or "botete." In addition, however, Seale states that there are thirteen other poisonous species of Tetraodontidae found in Philippine waters, and he says that, "Nearly all the natives of the Islands know that these fishes are poisonous, but either because of the peculiar flavor, or because of the ease with which they are caught, the fish are often eaten, and usually with deplorable results."

The problem of tetrodon poisoning in Malaya and Indo-China is, to say the least, twofold. Not only do individuals have to contend with poisoning from eating the fish but also from poisoning as a result of being bitten by it! Buddle mentions this fact in 1930:

" . . . another fact concerning this thoroughly unpleasant creature—that is, its habit of attacking bathers or fishermen wading in the sea, and inflicting a nasty bite which becomes septic. Moreover, its favourite point of attack is upon the genital organs."

Gimlette, in his book on Malay poisons says the responsible species are *Tetrodon fluviatilis* and *T. oblongus*, common to Malay rivers. It is questionable whether the wound becomes septic from mucus in the fish's mouth, venom, or the nature and position of the bite. The situation in Indo-China is described by Salanoue-Ipin in his medical thesis on the "vulnérant" *Tetrodon fluviatilis*.

Returning for the moment to Buddle, it is interesting that this author also considers the roe and gall bladder to be the poisonous organs of the fish, and says:

"The cleaning has to be done very carefully. It [*Tetrodon stellatus*] has to be skinned first, as the skin cannot be eaten and must not be cooked with the fish. The liver and gall-bladder have to be got out without breaking the gall-bladder. If this is broken, then the whole fish cannot be eaten."

Very little light has been shed on tetrodon poisoning in the West Indies. Disease from eating any fish is called "Ciguatera," whether it be produced from the inherent poison of the fish or from those toxins arising from putrefaction. Hoffmann, who has investigated the field of Ciguatera as a whole (1929), describes the general symptoms of Ciguatera, and states that fish of the genus *Tetrodon* are poisonous: "We have been shown that the tetrodon flesh is poisonous which has been used in California as small cakes spread out to kill stray dogs." Pellegrin, in his book on poisonous fish, notes that the

liver of *Tetrodon heraldi*, caught by local fishermen, was the organ used to make these lethal cakes for stray dogs in the La Paz section of Lower California. *T. heraldi* is known locally as "botete," the same name which is given to *Spheroides sceleratus*, poisonous in the Philippines. It should also be mentioned that Pellegrin gives a fine review of the poisonous species of the Tetraodontidae in various parts of the world.

The species responsible for what little poisoning occurs in Cuba are *Tetrodon testudinis* and *T. laevigatus*, commonly called "tambores." The ancient and widespread knowledge of the poisonous nature of tambores has reduced the problem to a minimum, which in part, at least, accounts for the fact that so little investigation has been carried out on the occurrence of the poison in the West Indies compared to that done by the Japanese. Thus, for example, little mention of tetrodon poisoning is made by Hill in Trinidad, again presumably because of the natives' taboo concerning the fish. It would appear, however, that the occurrence of *Tetrodon* poisoning in the West Indies would be an important step in determining the toxicity of other Atlantic species, particularly those of the east coast of the United States, and it is significant that tetrodon poisoning does occur in the West Indies.

TOXICITY AND CHEMISTRY

The Japanese, confronted with the problem of a delicious food fish being so poisonous, have taken up where Geerts and Remy left off. Their investigations from 1890 to the present day have been in three directions:

1. Determination of the localization of the poison in the tetrodon.
2. Isolation, purification, and determination of the chemical nature of the poison.
3. The poison's effect on its victims; symptoms and treatment.

The experiments on the localization of the tetrodon poison were begun by Miura and Takesaki in 1890 and were continued by Takahashi and Inoko in 1892. The former paper deals with one species, *Tetrodon rubripes*, each of whose organs these workers examined for presence of the poison between the end of March and the end of June. They extracted the poison separately from the ovary, liver, testes, kidneys, heart, spleen, skin, and skeletal muscle by macerating the tissues and using alcohol for extraction of the impure poison. It

should be mentioned, however, that Tahara (1910) showed that extraction with alcohol might be incomplete. Miura and Takesaki then injected the resultant extraction into rabbits and noted the effect and the time for reaction. They found that the most poisonous organ in *T. rubripes* is the ovary, which, however, is not poisonous when it is "spent." They noted that the effects of the poison on rabbits are cessation of respiration with the paralysis of the skeletal muscle, mydriasis, and cessation of heart beat.

The work of Takahashi and Inoko determined which of the species of *Tetrodon* common to Japan were the most poisonous and also what part of the fish was poisonous. They gave water extracts of the pulped organs to frogs and rabbits, and their results can best be presented in table form reproduced from their paper:

	Ovary	Testes	Liver	The rest of the viscera	Muscle	Blood
<i>T. chrysops</i>	+	+	+	+	—	n.e.
<i>T. pardalis</i>	+	+	+	+	—	+
<i>T. vermicularis</i>	+	+	+	+	—	+
<i>T. poecilonotus</i>	+	+	+	+	—	n.e.
<i>T. rubripes</i>	+	—	+	—	—	n.e.
<i>T. porphyreus</i>	+	—	—	—	—	n.e.
<i>T. stictionotus</i>	+	—	—	—	—	n.e.
<i>T. rivulatus</i>	+	n.e.	n.e.	n.e.	n.e.	n.e.
<i>T. cutaneus</i>	—	n.e.	—	—	—	n.e.

+ Trace or more of poison present.

— No trace of poison.

n.e. Organ or tissue not examined.

Takahashi and Inoko also observed that the poison found in the blood of the two species examined was only a trace, and that in the ovaries the toxic substance was strongest during the spawning period in some species. Furthermore, these experiments show that in the tetrodons under examination, the ovary and the liver were the two most toxic organs and that the skeletal muscle was free from poison. The presence of poison in the blood, however, might make the body toxic if the fish remained uncleared, although this seems improbable, since the poison which is in the blood apparently exists in such small amounts.

The purification and chemical study of tetrodon poison was begun in 1894 by Tahara. At that time he succeeded in isolating from the

ovaries of the ripe female fish an impure highly toxic substance which he called "tetrodon acid" because it gave a salt-like metal compound. In 1910, however, he improved the extraction and purification of this tetrodon acid and renamed it "tetrodotoxin," since it proved not to be an acid.

The method used in 1894 consisted, in its simplest form, of pulping the ovaries with water, separating the crystalline substances from the mixture by dialysis, and precipitating the raw impure poison with alcohol from the dialysate. The new method described in 1910, using over 1400 ovaries of *Tetrodon porphyreus* and *T. vermicularis*, was a great improvement over that mentioned above, since it obviated the necessity of the tedious dialysis. Most of the protein impurities were removed from the aqueous extract by acidification with acetic acid. The acid solution was treated with lead acetate and ammonia which caused the poison to precipitate along with lead hydroxide. After removing the lead with hydrogen sulphide, the filtrate was concentrated by evaporation. Part of the poison was precipitated with alcohol and the greater portion remained in solution.

The results of Tahara's work are as follows: Tetrodotoxin exists as a white, hygroscopic powder, very readily soluble in water and insoluble in the ordinary organic solvents. It consists of carbon, hydrogen, oxygen, and nitrogen; the provisional chemical formula is assigned as $C_{16}H_{31}NO_{16}$. The substance does not give any of the protein reactions nor is it precipitated by the alkaloidal reagents. The possibility that the poison is a protamine derivative is entirely excluded. The lethal dose with tetrodotoxin obtained by the new method is 4 mg. per kgm. body weight. In addition to the tetrodotoxin, a crystalline base, "tetronin," and a nitrogen free crystalline substance, "tetrodopen-tose," in smaller yield are always obtained. It is suggested that possibly the aforementioned substances do not exist in the organism as such, but are newly arisen through decomposition of the other products. On treatment with dilute hydrochloric acid the poison yields a crystalline base and an amorphous white powder of unknown character.

Other than statements to the effect that tetrodotoxin is neither a protein, an alkaloid, nor a protamine, Tahara does not go into the chemical structure of the poison. Subsequent investigations of tetrodotoxin have been directed at further purification and structural analysis of the poison.

Tahara's method of purification was used to obtain material used by Ishihara in 1924, at which time he stated that the poison is chemically an ester of glucose. This statement was challenged by Nagai and Ito (1939) because they found that "a reducing carbohydrate, which might have been considered the poisonous substance by Ishihara, is removed by means of AgNO_3 and seems to have no toxic value" and that "the nitrogen content in the purified poison is considerably higher than Tahara's." Some tests on the poison were done by Nagai and Ito and the following was deduced: all of the nitrogen may exist as amine, being attacked by HNO_2 ; 30% of the total amines are combined in amide form; the watery solution of the purified poison turns the polarization plane to the left; its $[\alpha]_D^{15}$ is -22.85 ; it seems probable that the poison is an acyclic compound. The authors did not use tetrodotoxin as purified by Tahara; instead they devised a different method and confined their efforts to *Spheroides rubripes*. They also intended to isolate the poison in crystalline form but were unsuccessful.

Apart from the Japanese work, recent studies by Macht and Spencer (1941) are of particular interest in that they deal with *Spheroides maculatus*, the Atlantic puffer. These investigators tested the toxicity of fresh muscle extracts of 65 different species of fish, both phytopharmacologically (by studying the growth of *Lupinus albus* seedlings) and zoopharmacologically (by intraperitoneal injections into white mice). They found that the extracts from nine species of fish, among which was *S. maculatus*, were "definitely toxic for growth of *Lupinus albus* seedlings," and that they were also "profoundly toxic for white mice." This was not true of extracts from the other species. The original experiments were made with fresh unheated suspensions, but Macht and Spencer showed that although heating destroyed the toxicity of most of the muscle extracts, those from the Tetraodontidae and Diodontidae could be heated to 60°C . without decreasing their toxicity to any great extent.

ACTION AND SYMPTOMS

It has been previously noted that the early investigator, Remy, described the action of tetrodotoxin on the body and made the following generality which still holds true:

"The poison of the genital organs of the Tetrodons is a poison paralyzing the nervous centers which has a more or less strong

effect on the general and special sensibilities and on the motility, and effects death by suffocation."

Cases of the poisoning have been described by Cook, Forster, Remy, Takahashi and Inoko, and more recently (1927) by Leber. This latter case involves an Amboynese about thirty years old who became ill from eating *Tetrodon immaculata*. The symptoms are well described, especially the widespread and severe changes that occurred in the skin. The victim of the poisoning was treated successfully with intravenous injections of caffein, calcium, and stypticin (cotarnine hydrochloride). The symptoms and treatment show that in this instance the poison had great effect on the sensorium and vascular system.

The exact action of the poison, however, obviously must be determined by experimentation on animals as well as by the observation of specific cases in humans. The first group of these experiments was done by Remy and resulted in the statement quoted above. Ishihara (1924), in the same work wherein he describes experiments to determine the chemical nature of Tahara's tetrodotoxin, also describes work done to determine the pharmacological effect of the poison. He determined minimal lethal doses for about twenty different kinds of animals, both warm and cold blooded. Also he found that the paralysis affected the striated muscles and the autonomic nervous system, but did not affect the smooth muscles or the neuro-myo junction. This, however, was not confirmed by Kimura (see below).

The best work concerning the exact physiological disturbances of tetrodotoxin was done by Kimura in 1927. It is an extremely thorough study of the effects of Tahara's tetrodotoxin on the various organs and tissues of rabbits and frogs, both *in situ* and excised. He found a number of important facts, which can be summarized as follows: Tetrodotoxin loses its poisonous properties relatively quickly in animal bodies through some as yet unknown mechanism. But the poison is not detoxified due to the action of kidneys, liver, or muscle tissue. Some poison may be lost due to the alkalinity of the blood, but not enough to account for such a great difference in toxicity when the poison is injected slowly rather than quickly. Only adrenalin hinders the resorption of the tetrodotoxin through vasoconstriction, thus allowing the animal to bear more than the minimal lethal dose. Adrenalin, consequently, may be used effectively in the treatment of tetrodon poisoning under certain circumstances. The poison affects

the intestine by lowering tonus; with larger doses it increases tonus. These effects may be due to a paralysis of the vagus first, and then, with increasing amounts of the poison, paralysis of the sympathetic division. Tetrodotoxin affects the isolated living heart of the rabbit and the frog by decreasing the amplitude and frequency of the beat to a final diastolic stand-still. The poison has three successive actions on the heart—namely, paralysis of the impulse pathway so that sino-auricular and auriculo-ventricular dissociation is brought about, paralysis of the impulse center during which period the heart muscle will respond to mechanical stimulation, and finally, paralysis of the contractile fibers.

Yano, in 1938, experimenting with frogs and rabbits, attempted to determine whether the two most serious effects of tetrodon poisoning, *i. e.*, difficulty in breathing and a sharp decline in blood pressure, were due to inhibition (paralysis) or excitation, central or peripheral. Again tetrodotoxin prepared according to Tahara's method was used. Yano reached the following conclusions: the vasomotor center, course of the cardiac impulse, and cardiac muscle are paralyzed; tetrodotoxin paralyzes not only the vasoconstrictor nerves, but also the muscle of the blood vessel itself; in that case the decrease of blood pressure is caused by paralysis of the vasomotor center, vasoconstrictor nerves, peripheral blood vessels, and cardiac muscle; the poisonous action is very transient.

Concerning the treatment of cases of tetrodon poisoning, Yano goes on to say:

"One of the remarkable characteristics of this toxin is that the poisonous action is very transient. This makes the symptomatic treatment very promising. The most excellent result was obtained by coramin (cornidin) on the isolated frog heart as well as on the respiration and the blood-pressure of a live-rabbit. Tyramin is effective on the descending of blood-pressure. Coffein, lobelin, natrium-thiosulfate are potent for the disturbance of respiration. The intravenous infusion of much physiological salt solution combined with the above medicines gives a still better result."

DISCUSSION

From what has been said it is immediately apparent that poisoning by the Tetraodontidae has been recorded for at least two and a half centuries, and it is not unreasonable to suppose that it has been known for a much longer time. There has been relatively little work, however, on the possible toxicity of the Atlantic puffer, *Spheroides maculatus* (Bloch and Schneider), which has recently attained market status. This is explicable because the fish has been eaten to such a limited extent; also, if it be toxic and has caused any illness at all, the cases have been so rare as to attract little attention.

The review of the literature presented here indicates that in many Tetraodontidae the poison is associated with the gonads and liver, and there is also evidence that the degree of toxicity varies in some species and may be most severe at or near the time of spawning. If *Spheroides maculatus* is at all toxic, there are two factors, apart from its limited consumption, which have in all likelihood played a part in the failure to detect this condition. First, it has probably been efficiently cleaned and eaten shortly after its capture at points near the fisheries which take this species. Second, its consumption by humans has been mainly confined to the summer and early fall months, when for example it is taken most abundantly by Long Island fishermen; this period is, in the main, *after* the spawning season (Warfel, Merriman, and Olsen—MS.).

In view of the information presented herein, it is evident that toxicity tests should be undertaken on a seasonal basis and under varying conditions wherever this species is offered for sale. It is hoped that this paper may be of value in stimulating such research and in providing a review of the available pertinent information. Until such research is completed it would seem expedient if special care were exercised in the preparation of the common puffer, *Spheroides maculatus*, for market.—D. M.

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STUDIES ON THE MARINE RESOURCES OF SOUTHERN NEW ENGLAND

I. AN ANALYSIS OF THE FISH POPULATION OF THE SHORE ZONE¹

BY HERBERT E. WARFEL AND DANIEL MERRIMAN

Bingham Oceanographic Laboratory

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ABSTRACT

Regular biweekly haul-seine collections of fishes were made at Morris Cove, New Haven Harbor, Connecticut, from July 1942 through June 1943. The objectives were: 1. to determine the precise nature of the population; 2. to reveal methods needed for more detailed analyses of the life histories of the different fishes encountered; 3. to gather as much data as possible on the smaller inshore species—this information to form the basis for further studies of those fishes that are commercially important, either directly or indirectly. The collections involved 16,525 individuals distributed among 32 species.

An analysis of the fish population by species includes discussions of each of the 18 most abundant forms, of which the commonest were *Menidia menidia notata*, *Pseudopleuronectes americanus*, *Syngnathus fuscus*, *Fundulus heteroclitus* and *majalis*, and *Brevoortia tyrannus*. Length-frequency curves and life-history data are presented, and the problems arising from the spatial and temporal differences in the spawning of many of the individual species, as well as the resultant intermixture of the young produced at different periods and in different areas are emphasized.

There were definite relationships between temperature and the population of fishes as a whole as well as the component species. Low winter temperatures apparently excluded all species. Salinity was not a limiting factor. Abundance appeared to be conditioned in part by the degree of turbidity.

An analysis of the fish population as a whole includes classification on the basis of geographical distribution and size. Evidence is presented that the shore-zone fishes are definitely limited as to the size at which they occupy this biotope. With few exceptions the different species are not found in the area after they reach approximately 100 mm. This size stratification holds regardless of age.

That the sandy-bottom, shallow-water shore zone under consideration is a definite ecological entity is clear from the highly characteristic population of fishes it contained. The discussion of abundance involves consideration of a constantly shifting population of apical dominants at the peak of an Eltonian pyramid. In any ecosystem organized in trophic levels there are apical, intermediate, and basal dominants. The apical dominant includes the species of the highest level controlling the

biocoenosis. The basal dominant includes the controlling organisms at the lowest level. Normally the apical dominant will be the largest common predator, the basal dominant the major photosynthetic species. The composition of the aggregation of fishes here considered is never twice the same and the precise make-up of the peak of the Eltonian pyramid thus varies correspondingly.

The numbers of fishes are considered in terms of *relative* and *total* abundance. The former approach indicates the relative position of the various species on any given date, and when summarized gives a true expression of positional values regardless of the influence of extraordinary numbers of individuals present on any one day. The latter approach indicates the fluctuations in total numbers collected on one day; when summarized, the total abundance of a single species in terms of the percentage of the whole of the collections for the entire study is shown. Analysis of the total abundance of the species by collection dates suggests a possible effect of population pressure on the number of individuals, *i. e.*, the population of fishes showed a tendency to build up to maximal levels, with subsequent sudden dispersal, after which the numbers increased again until the quantities were sufficient to cause repetition of this cycle of events. Summarization of the data shows that the species occupying the first six ranks of relative abundance made up 92% of the volume of all the collections, but dominated the individual collections, and hence the fish population of the biotope, only 63% of the time.

INTRODUCTION

The present analysis is based on regular, biweekly haul-seine collections of fishes from Morris Cove, New Haven Harbor, Connecticut, over a complete year, from July 1942 through June 1943. There were three objectives in the work. The first was to determine the nature of the population—the permanent and transient residents found in that particular habitat, with special emphasis on the relative abundance of the various components on a seasonal basis. The second objective was to reveal methods needed for more detailed analyses of the life histories of the different fishes encountered. The third, and in many respects the most important, was to gather as much data as possible on the smaller inshore species—this information to form the basis for further studies of those fishes that are commercially important, either directly or indirectly. Some of the species of the shore zone of Long Island Sound are the young of individuals that later become significant elements in different commercial fisheries. Others may be important as sources of food for more desirable forms, or as competitors, either in the early stages of development when they live in the shore zone or later when they occupy deeper water habitats. Therefore, studies of this nature contribute directly to the solution of problems involving rational utilization, the causes of

fluctuations in abundance, and other fundamental aspects of fishery biology.

In all probability it would be possible to summarize the seasonal occurrence of the various species of fish of the Connecticut shore-line from the previously published reports of such authors as Baird (1889), Gill (1873, 1905), Goode and Bean (1879), T. H. Bean (1888, 1901, 1903), Tracy (1906, 1910), Fowler (1918), Gigelow and Welsh (1925), and Nichols and Breder (1926). However, compiling this information for the purposes outlined above would be difficult, inasmuch as most of these papers were not written with these objectives in mind. Further information along these lines is found in the works of Greeley (1939), Perlmutter (1939), and Pearse, Humm, and Wharton (1942); but even these differ in their approach. To accomplish the aims indicated above, therefore, it seemed desirable to conduct an investigation designed especially for the purpose. It is with the listed objectives in mind that this report is presented, in the hope that other investigators will find in it material for reference and comparison with data from other areas.

The Locality. Morris Cove is a curving beach approximately a mile in length on the east side of New Haven harbor. It has direct exposure to the west, but is sheltered from the open part of Long Island Sound a mile to the south by harbor breakwaters. The shore is lined with houses, and the area is popular with summer bathers—factors which contribute to the large amount of extraneous material which often lines the beach.

The slope of this cove is such that at no place does the depth exceed 12 feet at mean high tide, and at extreme low tide not over 50 yards of the bottom is exposed at any place. The bottom is predominantly sand, with occasional small and partially buried boulders which do not impede seining operations or offer shelter for fishes. Except for the fact that there are considerable areas of rocks at the extreme ends of the beach, Morris Cove could be described as a sandy beach biotope after the classification of Hesse, Allee and Schmidt (1937). Strictly speaking, however, two other limitations would need to be placed on this designation, for the area is not directly exposed to the sea, nor is it large in size when compared with the great expanses of beach on other sections of the Atlantic shore. Also, it should be emphasized that this study covered only a portion of the biotope, in that collections were made at low tide and did not extend far from the shore.

*Methods.*² All the fish were taken in a standard minnow seine, four feet deep and 30 feet long. Collections were always made during the low tide period. In general, hauls were roughly parallel to the shore line, except when the catch was brought to the beach at the conclusion of each seining operation. The area fished never exceeded a distance of more than 100 feet from the low tide mark, and the maximum depth reached by this method was four feet. Seining was confined essentially to the southern half of Morris Cove, and this area was worked in as uniform a manner as conditions permitted on each collection date. However, several times during the winter Morris Cove was frozen; under these circumstances hauls were made in nearby regions of much the same character, but where the type of exposure had prevented freezing. Since no fish were taken for some time before, on, or after the dates of freezing, there is every reason to assume that the validity of the data is in no way impaired by the fact that Morris Cove itself could not be seined on these occasions. In seining Morris Cove, the number of hauls varied with the conditions—*i. e.*, in some instances three long hauls were made, while in others six short drags were needed to cover the area effectively. But with the exception of the dates on which the cove was frozen, approximately the same area was worked as thoroughly as possible. Therefore, the fishing effort on each occasion can be considered roughly equivalent, and variations in abundance, as reflected in the catch, are probably reasonably accurate indications of population conditions in the area under consideration.

Notes on the temperature, tide, condition of the water, weather, etc., were made in the field, although full information is lacking for some collection dates (Table I). The temperature of the water was recorded regularly, and air temperatures were available from the local weather station. Water samples were taken at the time of collection, and the total salinity was determined in the laboratory by means of a suitable hydrometer.

² The authors were fortunate in receiving the help of Drs. Samuel F. Hildebrand and Charles M. Breder, Jr., in checking certain difficult identifications. They are also indebted to Yngve H. Olsen for his generous assistance both in the field and laboratory work, as well as in the preparation of the manuscript. They further take pleasure in acknowledging the help of various people associated with the Bingham Oceanographic Laboratory in different capacities since 1942—especially Andrew H. Wolff, Yale 1946, who did the illustrations in this paper, and Dr. G. E. Hutchinson, whose frequent suggestions and friendly interest have been a constant source of pleasure and stimulus to both authors.

TABLE I. FIELD DATA, MORRIS COVE, NEW HAVEN, CONNECTICUT, 1942-43

Date	Temperature in °C.		Weather	Tide	Water
	Air	Water			
VII-10-42	27.0	21.5	Hazy	Low	....
VII-24-42	25.6	25.1	Partly cloudy	Low	....
VIII-7-42	24.6	23.6	Partly cloudy	Low	....
VIII-21-42	28.2	26.8	Partly cloudy	Low	....
IX-4-42	25.9	23.9	Cloudy	Rising	....
IX-18-42	23.5	22.3	Overcast	Low	Calm
X-2-42	15.2	17.1	Fair	Low	Rough
X-16-42	17.0	16.6	Overcast	Low	Turbid
X-30-42	16.3	12.7	Clear	Low	Clear
XI-13-42	9.8	9.1	Overcast	Low	Very turbid
XI-26-42	9.8	8.1	Cloudy	....	Turbid
XII-11-42	2.9	4.2	Cloudy	Low	Slightly turbid
XII-24-42	2.2	-0.4	Overcast	Rising	....
I-8-43	-7.8	-0.3	Fair	Rising	Clear
I-22-43	0.0	1.2	Fair	Rising	Clear
II-5-43	4.4	0.5	Fair	Rising	Clear
II-19-43	2.8	0.6	Fair	Falling	....
III-5-43	7.2	-0.2	Hazy	Low	Rough
III-19-43	4.4	1.9	Rain	....	Clear
IV-1-43	9.0	5.6	Fog	Rising	Slightly turbid
IV-16-43	16.1	6.2	Snow	Falling	....
IV-30-43	23.5	7.3	Rain	Falling	Turbid
V-14-43	14.0	12.5	Clear	Low	....
V-28-43	21.0	18.4	Partly cloudy	Low	....
VI-11-43	22.5	19.4	Partly cloudy	Low	Turbid
VI-25-43	28.9	24.1	Hazy	Low	Very turbid

The fishes were preserved in 10% formalin in the field. Identification, sorting and measuring were done after preservation. Measurements were made to the nearest millimeter by means of dividers, the standard length being used throughout. The measurements were grouped by five-millimeter intervals, both in the presentation of length-frequency data and in the calculation of mean lengths wherever the number of specimens warranted such treatment. Exceptions were *Syngnathus fuscus* (Table IV, Fig. 6), where 10-millimeter intervals were used for both purposes, and *Clupea harengus* (Table XIV), where the data were grouped by two-millimeter intervals in calculating mean lengths. In Tables II-XXI the mean values for the standard lengths are listed for those collections and parts of collections that were relatively homogeneous, *i. e.*, where the range

was narrow and the numbers were large. Where the collection was small and the range wide-spread, no mean was calculated, but the values for the range in length are listed.

Identification of the fishes was checked with the aid of standard references for this region. Nichols and Breder (1926), Breder (1929), Hildebrand and Schroeder (1928), Bigelow and Welsh (1925), and Jordan and Evermann (1896-1900), were the principle sources, although more specialized material was used when necessary, *e. g.*, Hildebrand (1943), Norman (1934). The nomenclature used is largely that of Breder (*loc. cit.*), and the system of classification that of Jordan, Evermann, and Clark (1930); however, it should be mentioned in this connection that the system of Berg (1940) has many advantages.

ANALYSIS OF THE FISH POPULATION BY SPECIES

The total collections from Morris Cove involved more than 16,000 individuals. There were 32 species distributed among 21 families from 12 orders as shown below.

Order ISOSPONDYLI

Family CLUPEIDAE

Clupea harengus Linnaeus

Pomolobus pseudoharengus (Wilson)

Brevoortia tyrannus (Latrobe)

Family ENGRAULIDAE

Anchoa mitchilli (Cuvier and Valenciennes)

Family OSMERIDAE

Osmerus mordax (Mitchill)

Order APODES

Family ANGUILLIDAE

Anguilla rostrata (Le Sueur)

Order INIOMI

Family SYNODONTIDAE

Synodus foetens (Linnaeus)

Order CYPRINODONTES

Family CYPRINODONTIDAE

Fundulus heteroclitus (Linnaeus)

Fundulus majalis (Walbaum)

Order ANACANTHINI

Family GADIDAE

Pollachius virens (Linnaeus)*Microgadus tomcod* (Walbaum)*Urophycis tenuis* (Mitchill)*Urophycis regius* (Walbaum)

Order HETEROSOMATA

Family PLEURONECTIDAE

Pseudopleuronectes americanus (Walbaum)

Family BOTHIDAE

Scophthalmus aquosus (Mitchill)

Order THORACOSTEI

Family GASTEROSTEIDAE

Pygosteus pungitius (Linnaeus)*Apeltes quadracus* (Mitchill)

Family SYNGNATHIDAE

Syngnathus fuscus (Storer)

Order PERCOMORPHI

Family ATERINIDAE

Menidia menidia notata (Mitchill)

Family CARANGIDAE

Caranx hippos (Linnaeus)

Family POMATOMIDAE

Pomatomus saltatrix (Linnaeus)

Family SCIAENIDAE

Bairdiella chrysura (Lacépède)*Leiostomus xanthurus* (Lacépède)*Menticirrhus saxatilis* (Bloch and Schneider)*Cynoscion regalis* (Bloch and Schneider)

Order CATAPHRACTI

Family COTTIDAE

Myoxocephalus aeneus (Mitchill)

Family TRIGLIDAE

Prionotus evolans evolans (Linnaeus)*Prionotus carolinus* (Linnaeus)

Order PHARYNGOGNATHI

Family LABRIDAE

Tautoglabrus adspersus (Walbaum)*Tautoga onitis* (Linnaeus)

Order JUGULARES

Family BATRACHOIDIDAE

Opsanus tau (Linnaeus)

Order PLECTOGNATHI

Family TETRAODONTIDAE

Spheroides maculatus (Bloch and Schneider)

Before attempting comprehension of the total population of fishes at different times of year, or before any conclusions can be drawn as to the general nature and characteristics of the whole fish fauna, it is essential to consider the individual components as distinct entities. Hence each species is discussed separately below. Most of the material presented constitutes a brief summarization of pertinent data which provides certain evidence regarding the nature of the whole population. Also, each species obviously offers interesting possibilities for further and more detailed study. The arrangement of the following list is in order of abundance as determined by a scoring method which is described later (p. 80).

Menidia menidia notata (Mitchill)

The most persistent and abundant fish in the Morris Cove area was *Menidia menidia notata*. This species was taken 17 times out of a possible 26 and consistently ranked first in abundance from July through mid-October, 1942. On October 30 it was superseded by a large school of *Brevoortia tyrannus*, and on November 13, it was apparently driven out by very turbid water. On November 26 and December 11, *M. menidia notata* was again the most prevalent form, but by that time the temperatures were low and the numbers of individuals and species encountered had fallen considerably (Fig. 17). No silversides were taken from mid-December until the spring of 1943. *M. menidia notata* first appeared in mid-April which was the first collection of that year that contained an appreciable number of fishes, but at no time until June did it appear in large quantities. On June 11, under fairly favorable circumstances, larger numbers of these fish were taken as shown in the curve of abundance (Fig. 1). The last collection was made under unfavorable conditions, the water being turbid, so that the total number went down again. However, during

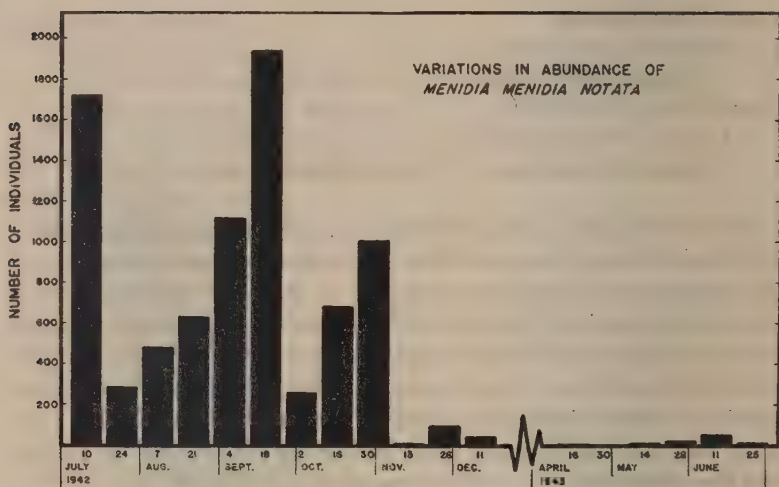


Figure 1. Variations in abundance of *Menidia menidia notata*. The break in the base line indicates the winter period when no fish were taken.

the last week in June, in the course of collections in the same area for other materials, general observations indicated that the population was tending to return to the original condition observed the previous year. On these trips gravid individuals of both sexes were encountered and a few scattered fish of-the-year (0+) were also taken for the first time in 1943.

Certain obvious trends in the numbers of *M. menidia notata* in the biweekly collections from July to November, 1942, are apparent in Fig. 1. It will be noted that following the peaks of abundance there was a sharp drop to a comparatively low level, and that on two occasions the numbers then gradually increased again. This suggests that *M. menidia notata* was a prominent part of a population of fishes which showed a tendency to build up to maximal levels until the area became overcrowded, with the result that sudden dispersal occurred, after which the numbers increased again until the quantities were sufficient to cause repetition of this cycle of events. This subject is more fully discussed in the section on the analysis of the fish population as a whole (pp. 83-85).

The first collection of *M. menidia notata* for this study was taken July 10, 1942, and consisted of 1722 individuals. With one exception,

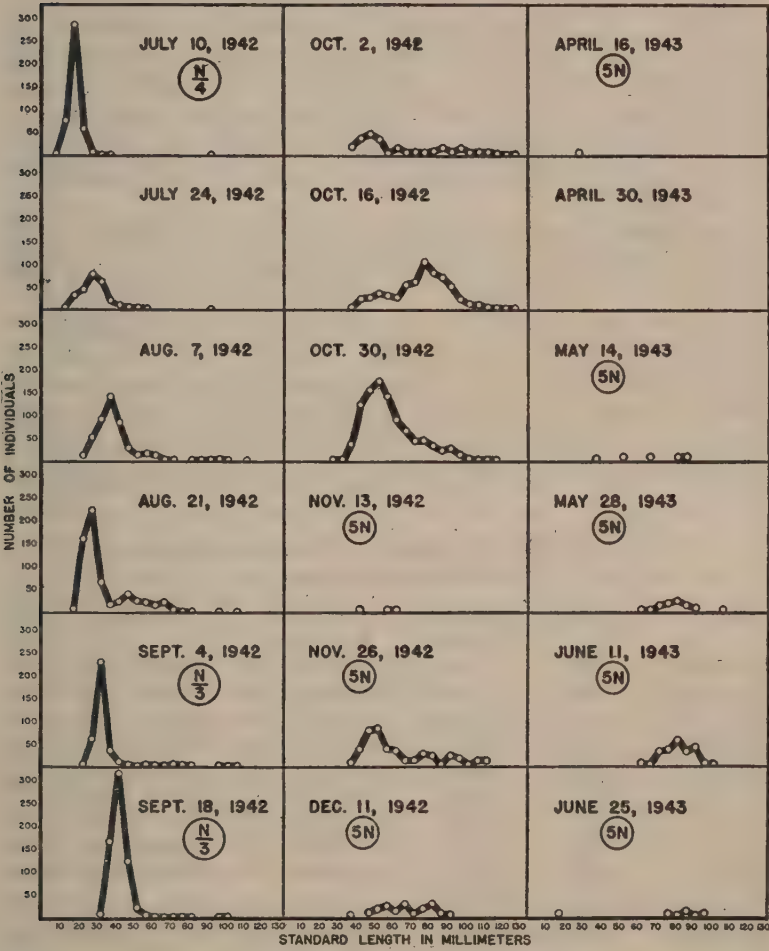


Figure 2. Length-frequency distribution of *Menidia menidia notata*. The encircled values represent adjustments of numbers of individuals to accommodate the data on one graph. $N/4$ indicates that the number of individuals has been divided by 4. $5N$ means the number of individuals has been multiplied by 5.

an individual 92 mm. long, it seems probable that all these were fish-of-the-year. It also seems probable that these fish developed in the neighborhood of Morris Cove since ripe individuals are encountered in that area in June, and also since the fish of the collection were so small as to make it unlikely that they had migrated any great distance. All but the single individual mentioned fell within the range from 7 to 39 mm., the mean being 16.99 mm. and the mode approaching the 15 mm. mark (Fig. 2).

The collection made on July 24 was considerably smaller, having only 282 individuals and was more heterogenous. The bulk of the collection fell within a range of 12 to 40 mm.; 23 fish were from 40 to 60 mm. long, and one was 95 mm. Exclusive of the latter specimen, the population had a mean standard length of 29.58 mm., and the mode was about 2 mm. less. It seems reasonable to assume that this collection represented the same population encountered two weeks earlier, and that the difference between the central tendencies is indicative of growth for that period, the increment being about 12.5 mm.

TABLE II. NUMBER, LENGTH, AND RANK OF ABUNDANCE OF
Menidia menidia notata

Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation	Rank
VII-10-42	1722	7- 92	16.99 ± .79*	3.30 ± .056	1
VII-24-42	282	12- 95	29.58 ± .37*	8.02 ± .341	1
VIII-7-42	479	20-114	40.03 ± .59	12.96 ± .419	1
VIII-21-42	629	19-106	33.25 ± .54*	13.53 ± .382	1
IX-4-42	1115	22-108	34.61 ± .31	10.47 ± .226	1
IX-18-42	1938	30-101	42.23 ± .11*	5.03 ± .081	1
X-2-42	254	35-127	64.03 ± 1.47	23.40 ± 1.04	1
X-16-42	661	35-129	74.98 ± .66	16.94 ± .47	1
X-30-42	1003	27-118	58.32 ± .48	15.27 ± 3.41	2
XI-13-42	3	42- 61	.....	.....	4
XI-26-42	88	37-112	65.00 ± 2.20	20.62 ± 1.55	1
XII-11-42	37	39-109	69.84 ± 2.44	14.63 ± 1.72	1
IV-16-43	1	....	.....	.....	..
V-14-43	9	37- 89	.....	.....	5
V-28-43	20	62-105	81.50 ± 2.15	9.64 ± 1.52	5
VI-11-43	49	62-101	82.20 ± 1.27	8.86 ± .895	3
VI-25-43	11	15- 97	.....	.....	4

* One or two large individuals, obviously out of the range of the main body of the collected population, omitted from the calculation of the mean. See Fig. 2.

The third collection, taken August 7, was larger than the previous one but not as large as the first. It was not as homogeneous as either of the other two, and contained a considerable number of large individuals. Most of the fish within the lower limits of the length-frequency curve (Fig. 2) were probably fish of the year; further study should demonstrate that they were of essentially the same population as were the fish of the earlier collections. There were also 39 fish ranging in standard length from 55 to 75 mm., which might have belonged either to this same group, or on the other hand, might have been related more nearly to the 13 additional individuals that occurred within the 80 to 114 mm. range.

The fourth collection, taken August 21, was of particular interest in that it was larger than the two previous hauls, and that the range for the whole was practically the same as the population taken two weeks earlier, yet the mean for the entire group was 6 mm. less than the collection of August 7. Thus the collection of August 7 had a mean standard length of 40.03 mm., and the modal value for the bulk of the collection fell in the neighborhood of 37 mm. The collection of August 21, however, had a mean standard length of 33.25 mm., and the modal value for the population was 27 mm., 10 mm. less than the collection immediately preceding. There are a number of possible explanations for the presence of the smaller fish. It is possible, but highly improbable, that the males and females have differential growth rates in this species, and that the first collections consisted of fish mainly of one sex, while the population under consideration was dominantly of the opposite sex. It might also be true that the collection of August 21 represented a later brood of fish spawned in the vicinity of Morris Cove. And it is further possible that this was an entirely new population, of essentially the same age as the previous individuals, but which had migrated from other areas. Of the last two conjectures the first seems the more logical, especially in view of the apparently somewhat protracted spawning season of this species; however, this would perhaps indicate a more definite spawning rhythm than is generally attributed to marine fishes. Three modes appear in the length-frequency curve (Fig. 2): one, around 27 mm., another in the 45-49 mm. frequency, and another in the 65-69 mm. grouping. On the basis of the length-frequency data alone, it would appear that in all probability there were three major components of the population as follows: several individuals of previous year-classes

grouped around the higher mode, fish of the original population for the area of the 1942 year-class near the middle mode, and around the lowest mode, 0+ fish of a new population either from a subsequent spawning in the same area or from a spawning elsewhere.

The first collection made in September was almost twice as large in numbers of individuals as the collection immediately preceding. However, in terms of standard length, it was essentially the same, the range and mean standard length differing but little from the collection of August 21 (Table II). The modal value for the principal peak of the curve, on the other hand, was about 5 mm. greater (Fig. 2). A few individuals, 40 in number, were grouped around the 57 mm. point, and 37 fish ranging in length from 70 to 109 mm. were present. But the bulk of the specimens seemed to be fish-of-the-year from the same population as those of the preceding collection.

The largest single collection of *M. menidia notata* was taken September 18, there being 1938 individuals. The mean standard length for this population, except for two individuals 97 and 101 mm. long, was 42.23 mm., and the mode for the curve fell at the same point. Of this large number of individuals, 1899 were within the range of length between 30 and 52 mm., and 39 were larger, including the two fish excluded from the calculation of the mean. This collection seemed to stand in relationship to the two previous populations in the same manner as did the collection taken August 7, and a peak of abundance for the second new population of 0+ fish was reached at this time. The measurements on the collections of August 21, September 4 and 18 indicate the rate of growth of this new population to a certain extent only, for presumably this second group of fish did not all appear simultaneously and mixed with the first group of 0+ individuals over a period of time, so that neither mean values nor length-frequency curves indicate more than general growth trends. It also seems apparent that the population taken in mid-September, along with the two previous collections, represented the product of the peak of the spawning season, which probably occurred in July rather than in June as Nichols and Breder (1926) indicate.

The collection taken October 2 showed an abrupt drop in numbers from that of the preceding collection date. While the mean standard length was high, there was a considerable variation in size. The population appeared to be made up of the remnants of 0+ fish represented in previous collections, as well as a few stragglers of previous

year-classes which were still in the vicinity and moving with the younger fish. Also there is the distinct possibility that the mode at the 45 to 49 mm. frequency represented a new wave of 0+ individuals from another area.

On October 16, 661 individuals were taken. The fish of this collection, while varying widely in standard length, were much larger on the average than any population encountered previously. A study of the length distribution of this collection leads to the conjecture that fish of the earlier populations (July 10, 24, and August 7), or those from another area and of an average size comparable to the previously studied collections, dominated the population again on this date.

While *M. menidia notata* was taken in great numbers on October 30, it was superseded for the first time in relative abundance by the appearance of a large group of *Brevoortia tyrannus*. *M. menidia notata* was relegated to second place in rank of abundance, yet the collection contained 1003 individuals. The mean standard length was smaller than at any time since mid-September and the abundance of individuals leads to the conclusion that again a new population had moved into Morris Cove. It also seems reasonable to assume that the forerunners of this group accounted for the small mode on the 47 and 52 mm. marks on October 2 and 16, the growth rates being slow at this time owing to falling temperatures.

November 13 was an unfavorable day for collecting, for a strong west wind prevailed and the water was extremely turbid. This collection contained but six species represented by 285 individuals. Only three *M. menidia notata* were taken, all of them fish that could have come from the population of the year since they ranged in size from 42 to 61 mm. Even so, *M. menidia notata* ranked fourth in abundance, the more abundant species being demersal and probably not so much affected by the extreme turbidity.

M. menidia notata was present in the area again on November 26, when 88 silversides were taken in a collection of 118 individuals distributed among four species. This was a widely divergent population ranging from 37 to 112 mm. in length. The lowest mode, which had the greatest frequency, fell near 50 mm. (Fig. 2). New individuals had apparently continued to come into the area, and remnants of previous populations were still present in small numbers. It is interesting to speculate on the age of the smaller individuals. These fish must have been the product of the latest spawning of the year—pos-

sibly even later than July—and their growth rates may have been impeded due to descending temperatures.

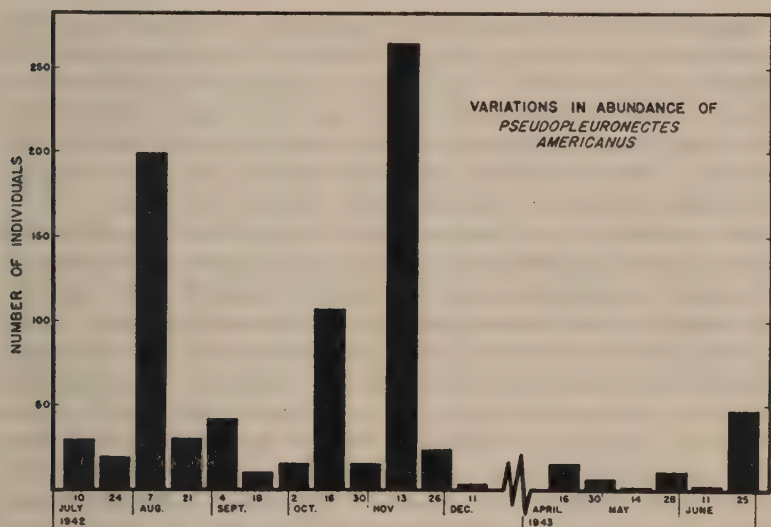
The last collection for the 1942 season was taken on December 11. This was a small lot of 37 individuals, with a range in length which was much the same as the previous group; they probably represented the same population.

No *M. menidia notata* were taken after December 11, 1942, until April 16, 1943, when one individual was collected. On May 14, one month later, nine more were netted ranging in size from 37 to 89 mm.; probably these were mainly fish that were just becoming one year old. Two weeks later, May 28, 20 *M. menidia notata* were taken and on June 11, 49 fish of this species were collected from the area. The mean standard lengths of the last two collections were approximately the same (81 to 82 mm., see Table II), and it is probable that they were the forerunners of the spawning population for the season. The last collection, that of June 25, 1943, contained but 11 fish; two were fish of the year of 1943 and measured 15 and 17 mm., and the others were within the range from 75 to 97 mm., so that it would appear that *M. menidia notata* had spawned by early June, 1943, and some eggs had hatched.

Pseudopleuronectes americanus (Walbaum)

Pseudopleuronectes americanus, the winter flounder, was the second most abundant fish found in Morris Cove. While it was taken 18 times out of a possible 26, which was once more than *Menidia menidia notata*, it was never as numerous in the single collections as the silver-side. On three occasions more than 100 individuals were taken, as shown by the three pronounced peaks of abundance indicated in Figure 3. *P. americanus* achieved first rank twice (Table III), was second in abundance on six occasions, third once, fourth four times, fifth once, sixth twice, and seventh once. It was represented by a lone individual in the otherwise abundant collection of May 14, 1943.

P. americanus disappeared in mid-December, 1942, and appeared again in mid-April, 1943. It thus coincided with *Menidia*, and, on the basis of consistent presence, both species can be called residents, although as nearly as can be judged by the data at hand, breeding winter flounders rarely, if ever, come into the area from which these fish were collected. The presence of a few larger *P. americanus* would seem to indicate that a population of older individuals exists at certain

Figure 3. Variations in abundance of *Pseudopleuronectes americanus*.TABLE III. NUMBER, LENGTH, AND RANK OF ABUNDANCE OF
Pseudopleuronectes americanus

Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation	Rank
VII-10-42	30	31- 56	42.1 $\pm$ 1.03	5.66 $\pm$.730	4
VII-24-42	20	33-101	.....	.....	5
VIII-7-42	199	27-117	46.4* $\pm$.623	8.27 $\pm$.441	2
VIII-21-42	31	27-102	43.6* $\pm$ 1.79	9.66 $\pm$ 1.27	7
IX-4-42	42	35-169	49.8* $\pm$ 1.35	8.32 $\pm$.950	4
IX-18-42	10	43- 66	.....	.....	6
X-2-42	16	40-101	.....	.....	4
X-16-42	107	35-127	57.9* $\pm$.964	9.74 $\pm$.682	2
X-30-42	16	42-131	.....	.....	3
XI-13-42	264	49-148	65.3* $\pm$.669	10.32 $\pm$.473	1
XI-26-42	24	63-138	.....	.....	2
XII-11-42	4	56- 83	.....	.....	2
IV-16-43	16	48-142	.....	.....	1
IV-30-43	11	38-141	.....	.....	2
V-14-43	1	51	.....	.....	..
V-28-43	11	55- 78	.....	.....	6
VI-11-43	2	61-132	.....	.....	4
VI-25-43	47	19-112	32.1* $\pm$.905	5.36 $\pm$.640	2

* Only those fish in the lowest mode calculated in the mean standard length. Limits of the curves expressed in terms of the mean values are indicated in Fig. 4.

times just a little further off shore, and this is confirmed in part by small trawl collections made in the vicinity of New Haven Harbor in March and April, 1943. The specimens taken in the small trawl at this time ranged in size from 50 to 275 mm., with most of the individuals in the higher frequencies and the mode falling between 210 and 230 mm. None of the fish taken from Morris Cove were this large, and comparatively few were more than 100 mm. in length.

Several factors enter into any study of the winter flounder which make it extremely difficult, on the basis of length alone, to arrive at justifiable conclusions in respect to population analyses. For example, the length of the spawning period is a complicating factor. Considerable difference of opinion concerning the exact period of spawning in the waters of southern New England is manifest throughout the literature, although all authorities are in agreement that *P. americanus* is a winter-spawning fish. Bigelow and Welsh (1925) state that spawning takes place from January through March; Tracy (1910) and Smith (1898) give February to April; and Perlmutter (1939) thinks the dates from mid-December through May are more nearly correct. Other opinions on this subject agree in that they all fall in the same general period, but the limits of the spawning time are uncertain.

Another complicating factor is the matter of races, or more or less distinct subdivisions within the species. DeKay (1842) recognized two divisions of *P. americanus* which he designated as species, and recently Perlmutter (1939) described the differences between so-called "bay" and "sea" flounders and inferred that they conform to the earlier descriptions of DeKay. Size differences in the fish encountered in an area such as Morris Cove might be due to racial differences, but a careful analysis of the population from all viewpoints would be necessary to verify this.

Another factor that renders an analysis on the basis of length uncertain in *P. americanus* (and unquestionably other species) is the matter of compensating growth pointed out by Bigelow and Welsh (1925). These investigators state, "The rate of development of the larvae is governed by temperature, occupying from about $2\frac{1}{2}$ to about $3\frac{1}{2}$ months, according to the data available, and the larvae hatched later may catch up with the earlier ones before metamorphosis." If this be true in southern New England, the difficulty of a population analysis on the basis of length is obvious, for this phenom-

enon would tend to minimize the effect of a protracted spawning period.

In order to obtain information concerning the age of *P. americanus* of the sizes taken in this work (and so as to preserve the Morris Cove collections intact since they will be studied in greater detail later), the otoliths and scales of a small sample of fish collected at Bushnell Beach, Pine Orchard, Connecticut during the summer of 1943 were examined. This locality, a few miles east of New Haven, is in many respects similar to the Morris Cove area, except that it faces the open Sound. This study indicated that those individuals ranging up to about 60 mm. were in their first year of growth, while those above 100 mm. were in their second year, thus confirming the statements of Bigelow and Welsh (1925) concerning growth during early life of this species in southern New England.

The first collection from Morris Cove, that of July 10, 1942, contained 30 individuals, ranging from 31 to 56 mm. in length. The mean length of this collection was 42 mm., and it seems reasonable to assume that these were all fish-of-the-year.

The collection of July 24 contained 18 fish of approximately the same range of standard lengths as those of two weeks before, and in addition two larger fish, 94 and 101 mm.; these two individuals were of the same general size as the larger fish of this species taken through most of the collecting season at Morris Cove (Fig. 4). This population consisted of two groups—apparently fish-of-the-year and two individuals of the 1941 year-class, if the analysis of the Bushnell Beach sample is applicable to the Morris Cove area. On the other hand, it is possible that the two groups represent separate races produced in the same spawning season; however, it is improbable that the larger fish could have grown approximately 100 mm. during the period from spawning to July 24, when they were taken, especially since they would have had the benefit of only a relatively short period of good growth conditions.

The collection made on August 7 consisted of 199 individuals, which were divisible into two distinct groups, on the basis of length. The larger group, 176 fish, had a mean standard length of 46.4 mm. and were fish-of-the-year. The smaller group, in which the fish ranged from 83 to 117 mm., were either fish of the previous year-class, or fish of another race, as indicated above.

The collection made August 21 included 31 individuals, two of

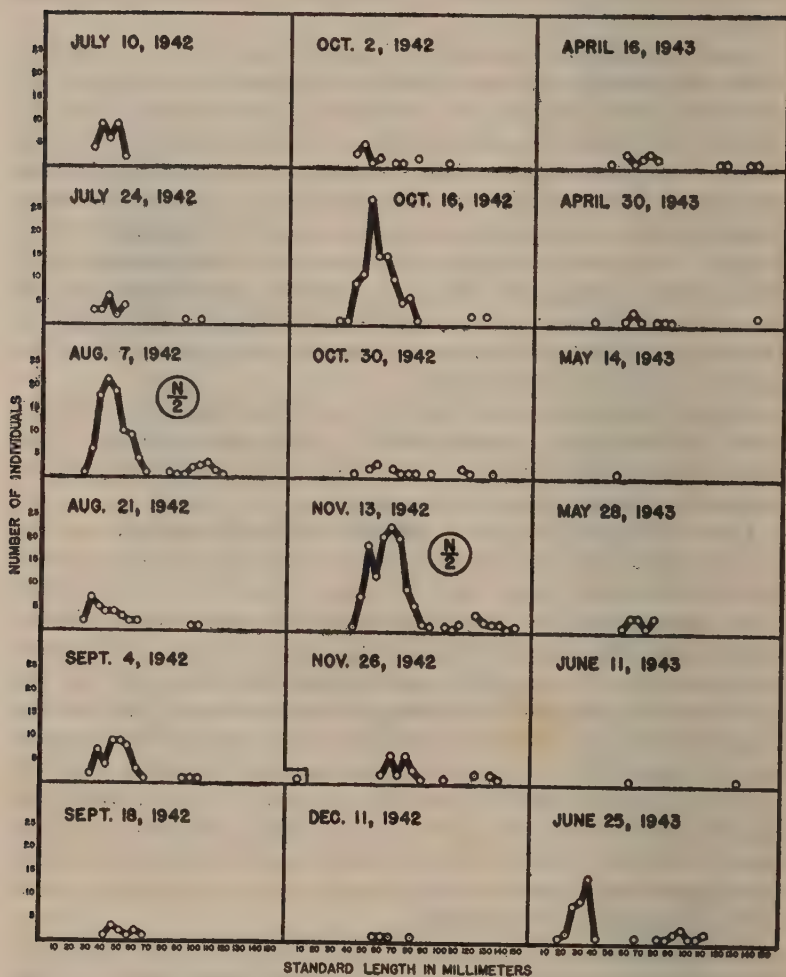


Figure 4. Length-frequency curves for *Pseudopleuronectes americanus*. The encircled figures indicate that the numbers of individuals have been divided by 2 to accommodate the data to the graph.

which approached 100 mm. in length, while the balance of the population ranged from 27 to 65 mm. and had a mean length of 43.4 mm. This mean length of the smaller individuals of the collection was less than that of the similar part of the collection made August 7 and is probably indicative of a new population of *P. americanus*. It should be mentioned, however, that since the sample of August 21 was small in numbers, direct comparison may not be justified. But if the phenomenon of compensatory growth is general in this species, added evidence that a different group of fish were taken in this collection can be derived from the lower mean and general spread of this mode (Fig. 4). On the basis of the available information, therefore, it seems most reasonable to assign the collection of August 21 to the status of a new population for the area.

The collection of September 4 contained 42 fish, which can be subdivided into two main size groups in a manner similar to the three previous hauls. The mean of the lower mode was 49.8 mm., which represents an increment of 6.2 mm. in the preceding two weeks. Apart from the two main size-groups of this population, one other specimen was taken, 169 mm. in standard length, the largest individual of this species taken during the course of the study.

On September 18 only 10 specimens of *P. americanus* were taken. This was one of the smallest collections made. All appeared to be fish-of-the-year, and reference to the length-frequency curve for this date indicates a growth of about the same order of magnitude as the previous biweekly collection showed over that of August 21. It seems probable that the fish taken in the second half of August and throughout September were all of the same population.

The first collection in October contained 16 individuals, 15 of which ranged from 40 to 82 mm. in length, the other being 101 mm. long. On October 16, 107 individuals were netted, 102 of which were within the range from 35 to 81 mm. The mean standard length of those individuals was 57.9 mm. The five additional individuals ranged from 116 to 127 mm. The collection of October 30 was low in numbers again, containing but 16 specimens, 12 of which ranged from 42 to 92 mm. and five from 111 to 131 mm. It is difficult and probably not profitable to speculate on the homogeneity of the October collections, but there is some evidence from the spread of the length-frequency curves that members of both the previously mentioned populations might have been present.

On November 13 the largest number of *P. americanus* taken in the course of this study was collected—264 specimens. In this group 238 individuals fell in the range from 43 to 94 mm., with a mean of 65.3 mm. Two modes are apparent in this curve, one near the 50 mm. mark and one at approximately 65 mm.; these are suggestive of the two different populations. The other 26 individuals were widely distributed between 103 and 148 mm. This was the only date on which *P. americanus* achieved the first rank of abundance in 1942.

The collection of November 26 showed considerable recession in numbers present in the Morris Cove area, only 24 specimens being taken. Of this small number, 18 were in the 63 to 87 mm. range and showed a bimodal tendency, while six were distributed between 101 and 138 mm.

The last collection taken in 1942 was that of December 11, when four fish, ranging in standard length from 56 to 83 mm., were seined.

The steady upward progression of the mean values for the standard length during the months of September, October, and November (Table III) are probably not accurate indications of the growth of individual groups or populations of the winter flounder, but unless different races are represented in the collections these values may be said to represent the general increment for that period for *P. americanus* in the region under consideration.

In the spring of 1943 the collections contained small numbers of individuals, but the range in size was much the same as those for the preceding fall season, except for the last collection in June (Table III). *P. americanus* returned to Morris Cove on April 16, when 16 individuals were collected and this species ranked first in abundance. Two weeks later, on April 30, 11 individuals were taken, and on May 14, only one was collected. On the next date, May 28, 11 fish were netted, and on June 11, only two were taken. Most of the fish contained in those small collections ranged from 50 to 75 mm. The lower limits of the range for each collection, as well as the higher, were much the same as those for the fall, as indicated above. Thus it would seem that little if any growth took place during the winter months in this species. However, this may not be a completely accurate picture, since there is evidence for a size stratification, particularly as regards flounders—that is, there seems to be a definite size limit to the fish encountered in the shallow water of the shore zone. Furthermore, the spring collections as a whole indicate that

regardless of the age of the individuals concerned (in this case fish probably entering the second year), they seek an environment that is compatible with their size (pp. 75-76).

On June 25, 47 individuals were collected. These were the smallest fish of the species taken during the entire study. Thirty-five of them ranged from 19 to 43 mm. and were, no doubt, fish of the year 1943. The mean standard length of that part of the collection was 32.1 mm. Of the balance of the collection it seems logical to believe that they were fish of the year 1942, which, for the most part, had returned to the area and would not leave until they had grown to approximately 100 mm. in length.

Syngnathus fuscus (Storer)

Third in rank of abundance in the collections, though not in that rank by virtue of the total numbers taken, was *Syngnathus fuscus*, the pipefish. This fish was consistently present in Morris Cove during the spring, summer, and fall months (Fig. 5). During this time it

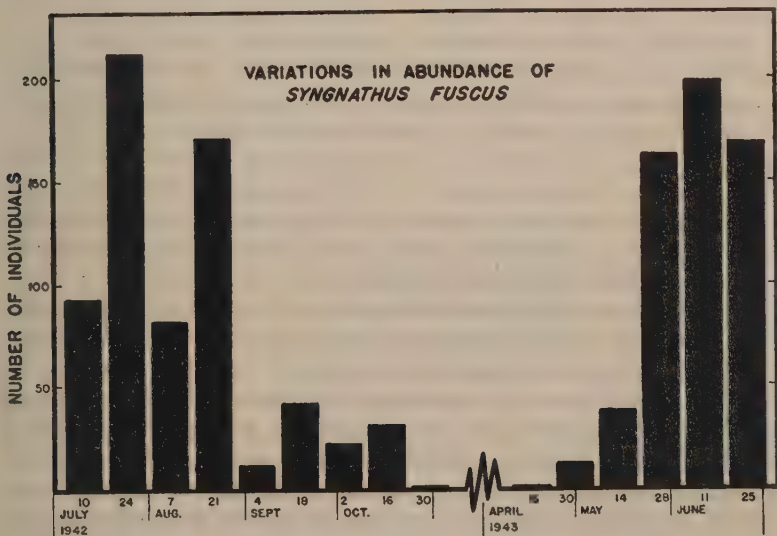


Figure 5. Variations in abundance of *Syngnathus fuscus*.

ranked first in abundance twice, second five times, and third four (Table IV). The month of September marked a period of compara-

TABLE IV. NUMBER, LENGTH AND RANK OF ABUNDANCE OF
Syngnathus fuscus

Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation	Rank
VII-10-42 ¹	93	32-213	.....	.....	3
	19	32-84	58.7 ± 0.25	10.9 ± 1.77	..
	74	131-213	169.0 ± 2.21	19.0 ± 1.56	..
VII-24-42 ¹	212	39-220	.....	.....	2
	170	39-113	74.0 ± 1.34	17.5 ± 0.95	..
	42	136-220	174.5 ± 3.27	21.2 ± 2.30	..
VIII-7-42	82	44-193	94.6* ± 1.87	16.8 ± 1.21	3
VIII-21-42	171	42-137	86.9 ± 1.35	17.7 ± 0.96	3
IX-4-42	14	90-121	.....	.....	5
IX-18-42	42	49-154	96.6 ± 3.16	20.4 ± 2.22	4
X-2-42	22	59-144	93.1 ± 4.90	23.0 ± 3.47	3
X-16-42	31	65-165	100.9 ± 4.09	22.8 ± 2.89	4
X-30-42	1	123	.....	.....	..
IV-16-43	1	153	.....	.....	..
IV-30-43	12	114-227	.....	.....	1
V-14-43	39	114-219	160.9 ± 3.79	23.6 ± 2.67	2
V-28-43	161	92-234	160.5 ± 2.48	31.5 ± 1.76	2
VI-11-43	199	104-221	160.6 ± 1.93	27.3 ± 1.37	2
VI-25-43	169	124-238	163.3 ± 1.77	23.0 ± 1.25	1

¹ Means for the two obvious subdivisions of the population computed separately.

* Isolated, large individuals not included in the mean value.

tive scarcity, which coincided with the appearance of *Fundulus* spp. and *Brevoortia tyrannus* in considerable numbers. *Syngnathus fuscus* disappeared six weeks earlier than most of the permanent residents of the immediate shore zone, but was one of the first species to reappear in the spring. The water temperatures on the dates of departure and arrival were 12.7° C. (October 30, 1942) and 6.2° C. (April 16, 1943).

The life history of this species, as indicated in the literature, is not at all clear, and there is considerable diversity of opinion concerning the fundamental aspects of development and growth. The breeding date is given by Bigelow and Welsh (1925) as March to August for southern New England; Nichols and Breder (1926) list May 13 as the earliest breeding date, and June throughout July for spawning; and Hildebrand and Schroeder (1928) say that "spawning takes place from April to October" for the Chesapeake Bay region. Bigelow and Welsh (*loc. cit.*) further quote Gudger (1906) as saying that the period from fertilization to parturition is ten days, and Tracy (1910) has

observed growth from 10 to 70 mm. in two months. Bigelow and Welsh believe that maturity is reached in about a year. Much of the published data concerns the phenomena associated with the method of breeding, and many of the conclusions reached by American investigators are based largely upon observations by European workers.

The first collection of this species was taken July 10, 1942, and contained 93 individuals. *S. fuscus* was the second most abundant form on that date, ranking next to *M. menidia notata*. The members of this collection fell into two readily recognizable length categories, 19 individuals ranging in length from 32 to 84 mm. and 74 from 131 to 213 mm. These differences in length were pronounced (Fig. 6) and seem to indicate age distinctions, although the larger fish were predominantly males, the majority of which were carrying larvae in their pseudo-marsupia. The smaller fish may have been either individuals in or entering their second year, or fish-of-the-year that had been spawned early, as indicated by Bigelow and Welsh, and had grown at the rate indicated by Tracy (1910).

The collection of July 24 contained 212 individuals, which also were divisible into two size-classes. The smaller, as judged by a comparison of the length-frequency curves, seemed to belong to the same population as those of the similar group from the previous collection; the larger fish, while slightly longer than the large individuals taken two weeks earlier, also matched its corresponding population. Two modes appeared in the length-frequency curve for the smaller fish in this collection, and this suggests the possibility of subdivisions within that portion of the population. A comparison of the means of the two collections of smaller fish on July 10 and July 24 gives an indication of the growth of individuals in that size category during the two weeks, if it be assumed that the same population was present over this period. The difference of 15.3 mm. is remarkably close to the growth rate indicated by Tracy (*loc. cit.*).

The collection of *S. fuscus* taken on August 7 contained 82 individuals, all except one of which corresponded to the smaller size-groups taken on the two previous dates. The single individual measured 193 mm., and was probably representative of the larger, mature individuals of the former collections. If the smaller fish can be considered members of the corresponding population which appeared in previous collections, the average growth rate was fast, for the difference between the mean standard lengths for July 24 and August 7 was 20.6 mm.

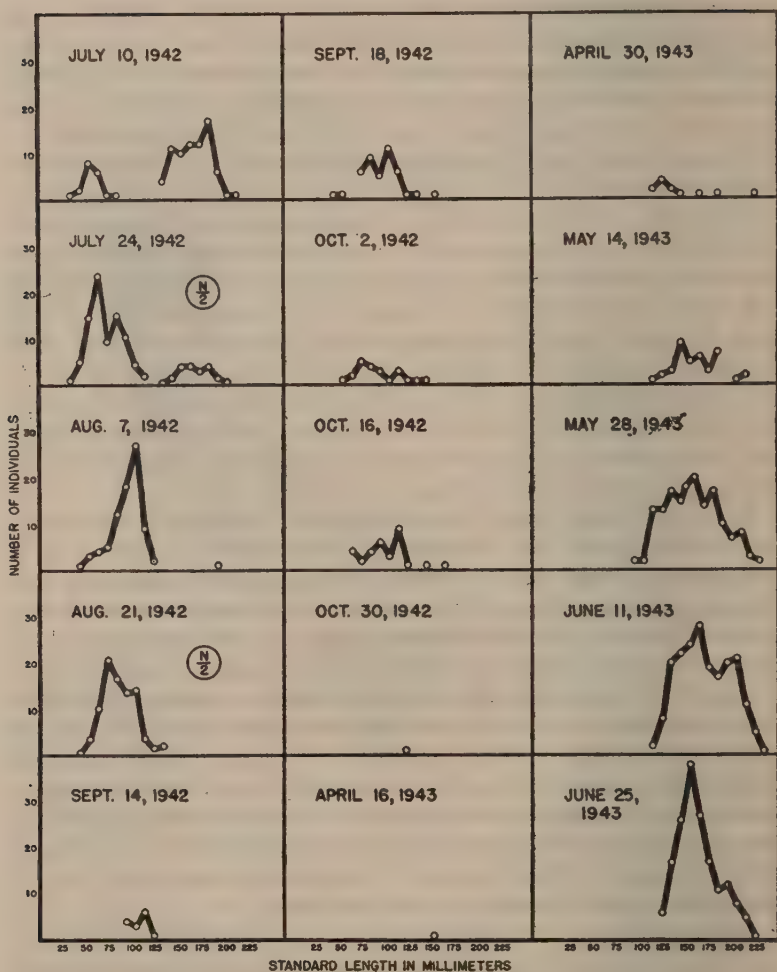


Figure 6. Length-frequency curves of *Syngnathus fuscus*.

On August 21 a collection of 171 individuals was obtained in which no large, mature fish occurred. That this was made up mainly of a new population seems to be indicated by the fact that the mean length was 7.7 mm. below that of the smaller fish of August 7.

Only 14 specimens of *S. fuscus* were taken on September 4, and the range of lengths indicated that they were a remnant of the collection taken two weeks previously. The next three collections were small and of about the same mean length (Table IV). It is perhaps significant that, except for the mature fish apparently in the area for spawning purposes, relatively few individuals larger than 100 mm. were encountered.

Collections made in the spring of 1943 consisted almost entirely of mature individuals, the males of which were carrying young after early June. The collection taken April 30 contained a few *S. fuscus* comparable in size to the larger individuals collected the previous autumn. The subsequent spring samples were similar to one another in that they showed much the same size range and mean length values throughout (Fig. 6 and Table IV).

From the foregoing description of the collections of *S. fuscus* it becomes apparent that several past assumptions regarding the life history are at variance with findings in the present study, and it is difficult to relate the statements of other observers to the condition of the fish examined in collections from Morris Cove. All "spawning" fish in this area—that is, females with ripe eggs or males carrying developing young—were collected in June and July; there was no indication of "spawning" after late July, or possibly early in August. This accords with Nichols and Breder (1926), but offers no confirmation for the statement of Bigelow and Welsh (1925) concerning March spawning. On the other hand, it is possible that the smaller fish encountered in the Morris Cove collections of July and early August conceivably might have been the result of early (spring) spawning in other areas. If such were the case, breeding activity and brood pouch development would have taken place at least as early as May if Tracy's (1910) estimate of growth is valid for early spring in southern New England, and if the brood period is ten days as indicated by Gudger (1906). It seems reasonable to suppose, however, that Tracy's estimates (which were made in the summer months) would not hold for the spring, that development would be much slower at that time, and therefore spawning would have occurred before May. Nichols and Breder (1926) found a post-larval individual somewhat off shore which may be taken as an indication that young *S. fuscus* are pelagic for the first few weeks of life. This might account for the fact that individuals below 30 mm. were not taken

during the course of the Morris Cove study, and it might also serve to explain the presence of the comparatively well developed individuals of the smaller size classes in on-shore waters where presumably no spawning individuals were available to produce them.

Be this as it may, the breeding activity of *S. fuscus* in Morris Cove was confined to the months of June and July. The eggs in the brood pouches taken in early June were in an early stage of development. Males examined two weeks later had eggs that were eyed, although little pigment had developed; by the end of the month (June 25, 1943) many of the individuals examined had embryos with definitely pigmented eyes. Mature fish, many with full brood pouches, were taken in July, 1942, but by August only one definitely mature individual was found, a female that had all the appearances of having missed the breeding period in that she carried a number of large eggs in her ovaries. On the basis of the Morris Cove observations, therefore, it would seem that breeding did not take place until late May. By middle to late June breeding was complete and the males were carrying embryos, most of which were still in relatively early stages of development. Parturition took place mainly in July, and by August all reproductive activity was complete. Therefore, the small-sized individuals (averaging 59 to 95 mm. in length—Table IV) so prominent in the collections of July and August were either fish-of-the-year which had been produced much earlier in another breeding area and had moved into the shore zone following a brief pelagic existence, or they were fish of the previous year. The latter possibility receives support from several incidental collections made in Morris Cove and other localities on the coast during July and August of 1943. These samples contained a group of *S. fuscus*, averaging approximately 35 mm. in length—fish which were without question a product of the 1943 spawning season. If these were fish of the current year, the small fish of the July–August (1942) collections may have been members of the 1941 year-class which were immature. This would mean that the large, obviously mature individuals in the collection were two years old or more, which is at variance with Bigelow and Welsh's (1925) estimate of one year for the age at maturity. And it would also mean that Tracy's (1910) observations of the growth rate of the young are not characteristic of fish in their normal habitat. It is readily apparent that there is much room for study on the spawning period, rate of development and growth, etc., in *S. fuscus*.

Fundulus heteroclitus (Linnaeus) and *Fundulus majalis* Walbaum³

Two members of the genus *Fundulus* were collected during the course of this study, *F. heteroclitus* and *F. majalis*. Since they were both present at essentially the same times during the course of this study, although in varying relative numbers, and inasmuch as their general habitat preferences are somewhat similar, they are dealt with as a unit in the present discussion.

In July and early August, 1942, the collections of *Fundulus* species were inadvertently discarded; consequently the data on the relative abundance of all species for that period, as well as the entire data for

³ Due to general lack of uniformity in the literature regarding the distinguishing features of *F. heteroclitus* and *F. majalis*, a critical study of the more common characters used in the recognition of these forms was attempted. Coloration, while often referred to, is difficult to use because of differences resulting from increasing age, pronounced sexual variations, and preservation. Therefore morphological features were evaluated for 50 fish of each species of all sizes and ages, and the most useful are set forth below. Depth measurements were taken across the base of the pectoral rather than across the deepest part of the abdomen in order to eliminate seasonal variations between "ripe" and non-gravid individuals. The standard length was used in all cases.

F. heteroclitus: Head short, 3.5 in length; depth 4.4; caudal peduncle 6.8. Eye 3.5 in head; snout 3.6; interorbital space 2.4. Branchiostegals 5, rarely 6. D. 11-12.

F. majalis: Head long, 3.0 in length; depth 4.6; caudal peduncle 7.7. Eye 4.7 in head; snout 2.3; interorbital space 3.0. Branchiostegals 6. D. 13-14.

These proportions were tested to determine whether or not the ratios change with age, and in *F. heteroclitus* the interorbital space was found to be relatively larger in the older fish, while in the larger *F. majalis* the orbit was relatively smaller.

Several authorities have cited the external oviduct as a characteristic of *F. heteroclitus* females, but Jordan and Evermann (1896) described the same structure in *F. majalis*. They estimated the oviduct to be $\frac{1}{2}$ to $\frac{3}{4}$ the length of the first anal fin-ray in *F. heteroclitus* and stated that it extended far out on the margin of the fin in *F. majalis*. Measurements of 105 *F. heteroclitus* females showed that the oviduct constituted about 45% of the anterior margin of the anal except during the spawning season, whereas in gravid females taken in June it covered roughly 65% of the fin edge. It appears from this evidence that this structure varies in *F. heteroclitus* with the degree of seasonal maturity, becoming larger during spawning and receding afterwards. Insufficient specimens of *F. majalis* were collected during the spawning season to allow an evaluation of this relationship. However, an interesting trend was revealed between the length of the fish and the oviduct/anal ratio. Measurements of 17 females collected in September and October showed that the larger fish had the higher ratio and the smaller the lower, indicating that the oviduct becomes proportionately longer with age.

The authors are indebted to Pfc. Arthur J. Driscoll, Jr., for making the measurements and calculations.

the rank of abundance of these two species, is subject to that error. However, as memory serves, the collections made at that time were of insufficient size to affect the relative positions of the more abundant species, and could have caused only minor alterations in the species of lower rank, *i. e.*, changes which would be comparatively insignificant.

The first collection of *Fundulus* available for study was that taken August 21, 1942. This was a collection of 67 individuals, 61 of which were *F. heteroclitus*, and 6 were *F. majalis*. The *F. heteroclitus* were divisible, by inspection, into two length groups (Fig. 7). One group of smaller size, had a mean length of 27.2 mm. and contained 27 individuals; the other lot was made up of 34 individuals with a 64.6 mm. mean length (Table V). That these fish represented at least

TABLE V. NUMBER AND LENGTH OF *Fundulus heteroclitus*

Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation
VIII-21-42 ¹	61	19- 82	.....	.....
	27	19- 47	27.2 ± 1.40	7.27 ± .989
	34	59- 82	64.6 ± .91	5.33 ± .645
IX-4-42 ¹	168	20-100	.....	.....
	57	20- 58	36.3 ± 1.24	9.35 ± .875
	111	60-100	72.9 ± .86	9.05 ± .607
IX-18-42	19	25- 51	.....	.....
X-2-42	1	32	.....	.....
X-16-42	19	23- 83	.....	.....
X-30-42	1	44	.....	.....
XI-13-42	4	30- 84	.....	.....
V-14-43	31	29- 74	44.8 ± 2.31	12.85 ± 1.63
VI-11-43	1	37	.....	.....
VI-25-43	1	52	.....	.....

¹ Means for the two obvious subdivisions of the population computed separately.

two age groups is obvious. The larger fish may or may not have been of one age group, but apparently they were mature individuals which had spawned in the spring, while the smaller individuals were unquestionably fish-of-the-year. The *F. majalis* collected on the above date, averaged 36.6 mm., exhibited juvenile features, and were probably 0+ individuals.

The largest collection of *Fundulus* was taken on September 4 when 377 individuals were netted. Roughly 45% of those were *F. heteroclitus* and the rest *F. majalis*. The *F. heteroclitus* were again divisible

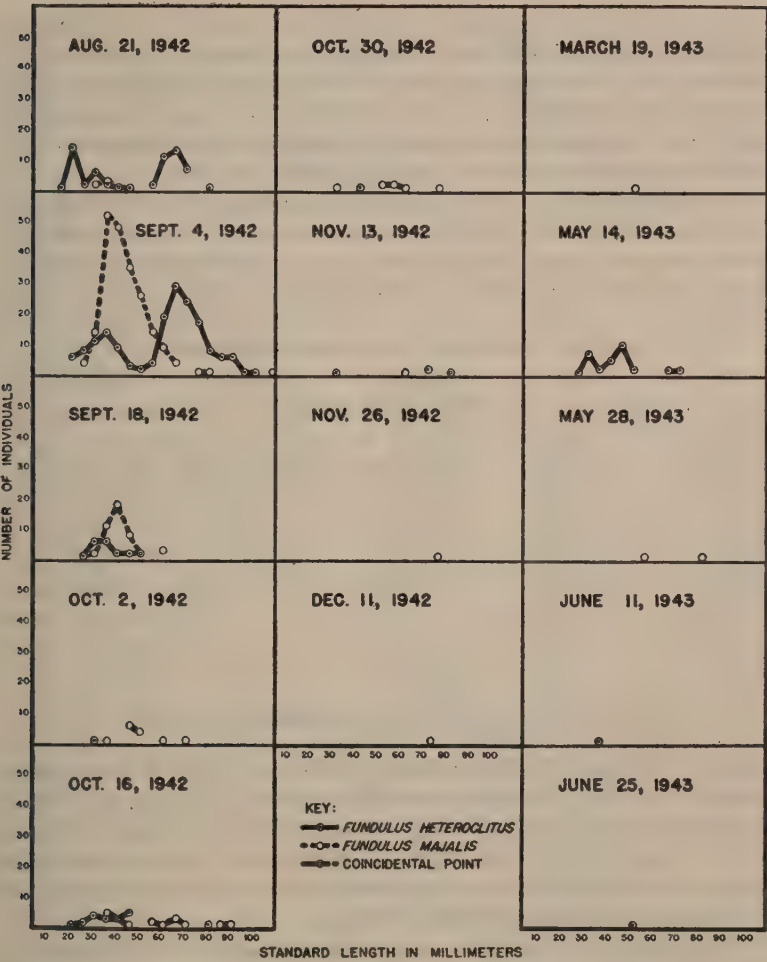


Figure 7. Length-frequency curves of *Fundulus heteroclitus* and *Fundulus majalis*.

into two groups, the smaller fish having a mean length of 36.3 mm., and the larger a mean length of 72.9 mm., thus indicating the general order of growth of the 0+ and mature fish. *F. majalis*, on the other hand, while having a fairly wide range in length, was apparently a homogenous population, except for a lone individual 112 mm. long.

The mean standard length of this collection, exclusive of the single large individual, was 44.6 mm. (Table VI), and there is good reason to conclude that the vast majority of these smaller specimens were immature fish-of-the-year. The single large fish was a female, whose ovary was compact and contained small eggs. Examination of its scales indicated that it was in its second year of growth.

On September 18, 64 specimens were collected that belonged to this genus, 19 of which were *F. heteroclitus* and 45 *F. majalis*. The *F. heteroclitus* were small, averaging 38.1 mm. and corresponding roughly to the smaller groups of the two previous collections. The 45 indi-

TABLE VI. NUMBER AND LENGTH OF *Fundulus majalis*

Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation
VIII-21-42	6	31- 44	.....	.....
IX-4-42	209	25-112	44.6* ± .640	9.24 ± .453
IX-18-42	45	29- 63	42.7 ± 1.06	7.13 ± .751
X-2-42	13	37- 70	.....	.....
X-16-42	18	36- 93	.....	.....
X-30-42	7	31- 79	.....	.....
XI-13-42	2	61- 83	.....	.....
XI-26-42	1	75	.....	.....
XII-11-42	1	74	.....	.....
III-19-43	1	50	.....	.....
V-28-43	2	59- 83	.....	.....

* One individual, 112 mm., not included in calculation of the mean.

viduals of *F. majalis* corresponded to the collection of that species taken before, except that the mean length of the population (42.7 mm.) was slightly less than that of the preceding sample owing to the absence of larger individuals approaching 80 mm. Some indication of the growth of the 0+ fish in this period is given by the progression of the modes of the length-frequency curves.

The collection taken two weeks later on October 2 contained but 14 individuals of this genus, all but one of which were *F. majalis*. The single *F. heteroclitus* was 32 mm. long, and the average length of the 13 *F. majalis* was 50.3 mm. Apparently these fish were immature, although the largest of them was beginning to show the marking of the female adult.

The collection of October 16 consisted of 37 individuals. The specimens of *F. heteroclitus* had a mean length of 37.6 mm., excluding

one individual 83 mm. long. The smaller fish ranged from 23 mm. to 49 mm. and were definitely fish-of-the-year, while the larger individual was an adult. *F. majalis* was represented by 18 fish with a mean length of 54.8 mm. The range in length of *F. majalis* from 36 to 93 mm. was a fairly evenly distributed variate, and most of these individuals were clearly immature fish-of-the-year; indeed, superficial examination of scales from the three larger fish, females which were assuming the adult color pattern, indicated that they were members of the 1942 year-class.

Only eight fish of this genus were collected on October 30, one *F. heteroclitus* and seven *F. majalis*. The *F. heteroclitus* was 44 mm. long and the *F. majalis* ranged from 31 to 79 mm. and appeared to be fish-of-the-year.

On November 13 four *F. heteroclitus* and two *F. majalis* were taken. The *F. heteroclitus* ranged from 30 to 84 mm., and the *F. majalis* from 61 to 83 mm. The small *F. heteroclitus* was a fish-of-the-year and the other three, measuring 73, 74, and 84 mm., were apparently adults, probably of the 1941 year-class. The *F. majalis* still possessed many juvenile characteristics. One *F. majalis* and no *F. heteroclitus* were taken on November 26, a collection in which only four species were represented. On December 11, one specimen of *F. majalis*, 74 mm. long, was collected; it was one of three species taken on that date.

No specimens of the genus *Fundulus* were taken again until March 19, 1943, when one specimen of *F. majalis* was netted, the only fish collected on that date. This specimen measured 50 mm. On May 14, 31 specimens of *F. heteroclitus* were taken, and the species ranked third in relative abundance. Many of these individuals were small (Table V) and had features generally ascribed to juvenile fish of the species. cursory examination of the scales of some of these specimens revealed annuli, thus indicating that they were members of the 1942 year-class. They were probably the product of an unusually late spawning. Two weeks later two specimens of *F. majalis* were netted which measured 59 and 83 mm. Other collections made at biweekly intervals in June resulted in the capture of one *F. heteroclitus* on June 11, and another of the same species on June 24.

The genus *Fundulus* was not very abundant along the shore line of the sandy beach in Morris Cove. It occupied a rank of abundance near the middle of the more common species, but never achieved the rank of first unless the single fish collected on March 19 is considered

(Table VII). On August 21 both species combined ranked fifth, and in the next collection, that of September 4, they ranked second—the date on which the greatest number of these fish were taken. The third largest collection, 64 individuals, was made on September 18 and the genus ranked third in relative abundance. Two weeks later the two species were in fifth place, and on October 16 they were third. During the next eight weeks they varied from third to fourth and after December 11 they were not taken again until mid-March, when the

TABLE VII. COMPARATIVE NUMBERS OF *Fundulus heteroclitus* AND *Fundulus majalis*.

Date	Numbers of <i>F. heteroclitus</i>	Numbers of <i>F. majalis</i>	Rank*
VIII-21-42	61	6	5
IX-4-42	168	209	2
IX-18-42	19	45	3
X-2-42	1	13	5
X-16-42	19	18	3
X-30-42	1	7	4
XI-13-42	4	2	3
XI-26-42		1	4
XII-11-42		1	3
III-19-43		1	1
V-14-43	31		3
V-28-43		2	..
VI-11-43	1	..	..
VI-25-43	1	..	..

* Rank of abundance is for the genus.

single specimen of *F. majalis* was netted. During the rest of the spring comparatively few specimens of either species were collected, and the genus only achieved a rank in relative abundance on May 14, when *F. heteroclitus* alone was represented. Among the possible explanations for the scarcity of these fish in the Morris Cove shore zone in the spring is the fact that these species were on spawning beds at some other type of biotope than that of the rather barren sandy beach at Morris Cove.

It is apparent from Table VII and Fig. 8 that approximately the same number of *F. heteroclitus* and *F. majalis* were collected during the season. Six of the collections contained more *F. heteroclitus* and eight held more *F. majalis*:

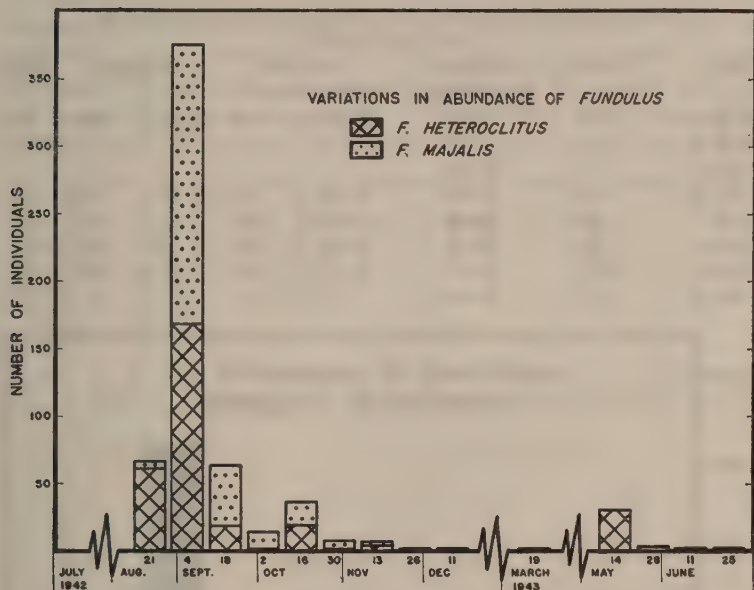


Figure 8. Variations in abundance of *Fundulus heteroclitus* and *Fundulus majalis*.

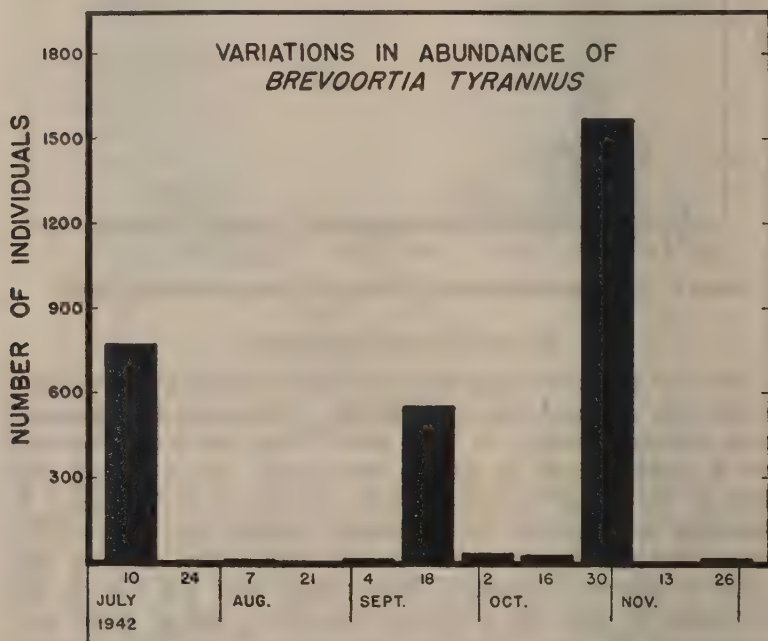
Brevoortia tyrannus (Latrobe)

The menhaden was among the more abundant fishes in Morris Cove during early July and again in early fall. This species first appeared in the collections on July 10, 1942, when 774 specimens were collected and it ranked second in relative abundance. One individual was obtained on August 7, and five fish were seined on September 4. Beginning in September and continuing through the month of October *Brevoortia tyrannus* was present consistently. During this period it was very abundant twice (Table VIII and Fig. 9)—on September 18, when 550 individuals were taken, and six weeks later on October 30, when 1565 fish were netted. The last collection November 26, contained but five individuals.

When *Brevoortia tyrannus* was present it was a comparatively important member of the population in terms of relative abundance. Of course it is impossible to say how long the separate schools of this species stayed in the area, but the wide variation in standard length for the different collections, as well as the irregular capture of extremely

TABLE VIII. NUMBER, LENGTH AND RANK OF ABUNDANCE OF
Brevoortia tyrannus

Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation	Rank
VII-10-42	774	9-45	24.79 $\pm$.152	4.23 $\pm$.110	2
VIII-7-42	1	27	.....	.....	..
IX-4-42	5	23-66	.....	.....	..
IX-18-42	550	31-79	57.25 $\pm$.530	12.42 $\pm$.374	2
X-2-42	30	34-56	43.50 $\pm$ 1.010	5.50 $\pm$.710	2
X-16-42	22	30-73	54.28 $\pm$ 2.220	10.40 $\pm$ 1.570	5
X-30-42	1565	30-71	48.73 $\pm$.555	6.95 $\pm$.394	1
XI-26-42	5	38-55	.....	.....	3

Figure 9. Variations in abundance of *Brevoortia tyrannus*.

large numbers, would seem to indicate that individual schools were moving along the shoreline during this season. It ranked first in abundance on October 30, was second on three occasions, third on November 26, fifth on October 16, and on two collection dates the numbers were so low that the fish was not ranked (Table VIII). It is

of interest that two peaks of abundance for this species, July 10 and September 18, coincided with the two highest peaks for all species (Fig. 20). But it should be noted that while the menhaden contributed to the height of the peaks for all species on these dates it was not the major element in either case. On the other hand, the peak at October 30 (Fig. 21) was caused mainly by the tremendous influx of

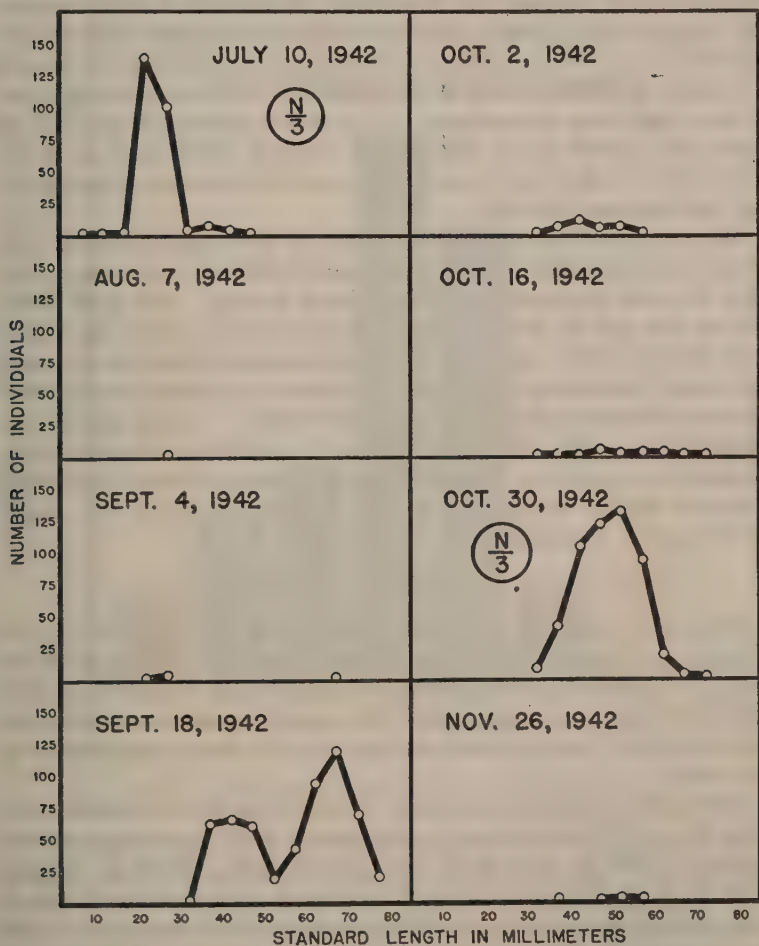


Figure 10. Length-frequency curves of *Brevoortia tyrannus*.

B. tyrannus. The wide range in numbers of menhaden during the season when they were taken was striking; they were either abundant, relatively few in numbers, or totally absent (Fig. 9). This fluctuation in numbers has been noted by Nichols and Breder (1926) who also cite large peaks of abundance in the early summer and fall.

The size of the individuals taken at Morris Cove indicates that they were all fish-of-the-year, but fluctuations in the mean length from one collecting period to another provides evidence of different populations (Table VIII). The collection of September 18 contained the largest fish taken, and that of July 10 the smallest. No individuals less than 9 mm. long were encountered. The rather consistent presence of menhaden around the 30 mm. length interval, which is at the lower limits of each collection, is also suggestive of the presence of successive new populations (Fig. 10).

The fact that the smallest fish collected were taken in early July seems to substantiate Nichols and Breder (1926) in their assumption that the peak of spawning in this region is in June. The wide variation in size and the fluctuation of the mean size points to agreement with Greeley (1939) who says, "A wide variation in the size of young was noted, indicating a long breeding season or possibly immigration of more advanced young from southern waters." In this connection, migration from the eastward should not be overlooked as a possibility, especially in regard to those fish taken in October which had mean standard lengths smaller than that for the fish taken two weeks previously in September.

Spheroides maculatus (Bloch and Schneider)

This species was taken in Morris Cove from early July until mid-October and was most abundant in late August and early September (Fig. 11). Almost all the individuals encountered in this study were small and were apparently fish-of-the-year, although large specimens are sometimes found in areas as near the tide line as the locality of this study.

Spheroides maculatus was fairly abundant in the collections from early July until mid-September and ranked sixth for the entire year. It ranked fifth in early July, third in late July, fourth in August, third in early September, and fifth later in that month. While it composed an important part of the shore zone fish population in the late summer, it did not exhibit the abrupt, erratic fluctuations in

number that characterized some of the more abundant forms. It gradually increased in numbers until it reached a peak on August 21, 1942; thereafter it decreased in abundance so that it was negligible after mid-September. The date of maximal quantities of *S. maculatus* did not coincide with the peak of the other species.

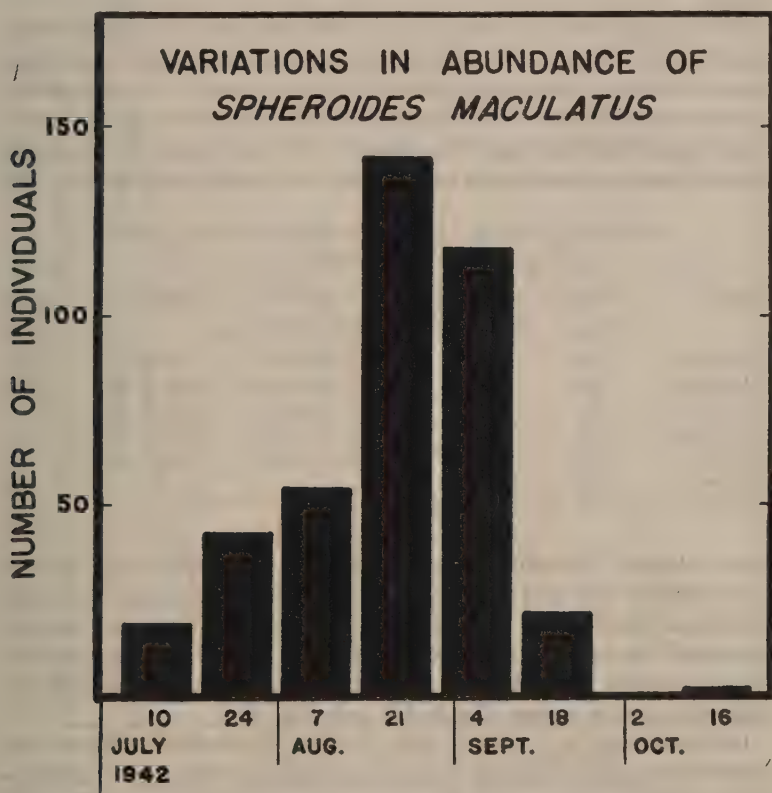


Figure 11. Variations in abundance of *Spheroides maculatus*.

This fish, which is quite common along the Atlantic coast, probably reaches a peak of spawning during the early summer. Bigelow and Welsh (1925) say they spawn from June on, in shallow water close to shore. Smith (1898) gives the date as June 1 to 10 at Woods Hole; Perlmutter (1939) indicates "May through August in Long Island;"

and Nichols and Breder (1926) agree with Smith for Woods Hole but state that ripe females have been taken as early as June 7 and as late as early September in the vicinity of New York, although in Sandy Hook Bay these authors found no ripe females after July 27. The evidence listed below points to a somewhat protracted spawning period.

The first collection, taken July 10, 1942, contained 19 fish having a mean length of 14.9 mm. This small collection was fairly homogeneous and without doubt consisted of fish-of-the-year. The next collection two weeks later also consisted of fish-of-the-year; they had a mean length slightly larger than that for the first collection, although some of the specimens were as small as those taken previously. The

TABLE IX. NUMBER, LENGTH AND RANK OF ABUNDANCE OF
Spheroides maculatus

Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation	Rank
VII-10-42	19	12-17	14.95 $\pm$.25	1.07 $\pm$.17	5
VII-24-42	43	11-25	16.90 $\pm$.50	3.28 $\pm$.35	3
VIII-7-42	55	16-28	20.10 $\pm$.33	2.44 $\pm$.23	4
VIII-21-42	142	14-35	26.00 $\pm$.40	4.73 $\pm$.28	4
IX-4-42	118	12-64	41.10 $\pm$.69	7.50 $\pm$.49	3
IX-18-42	22	14-74	.....	.....	5
X-16-42	2	27-32	.....	.....	..

third collection contained more *S. maculatus* and these also showed an increase in size over the previous lot. Likewise, the two following collections (the largest hauls of the season for this species) not only continued the trend of increased length, but also exhibited successively greater growth increments as judged by the mean lengths and the length-frequency curves (Table IX and Fig. 12).

On September 18 a much smaller collection was made than on any former date except July 10, but the size range was the widest encountered up to that time. In this group six individuals ranged from 14 to 18 mm. in length, five from 28 to 32 mm., six from 35 to 41 mm.; two were in the 50 to 60 mm. interval, two more in the 60 to 70 mm. interval, and one was 74 mm. No fish of this species were taken on October 2, and only two individuals, one 27 and another 32 mm. in length, were secured on October 16, which was the last time they were taken.

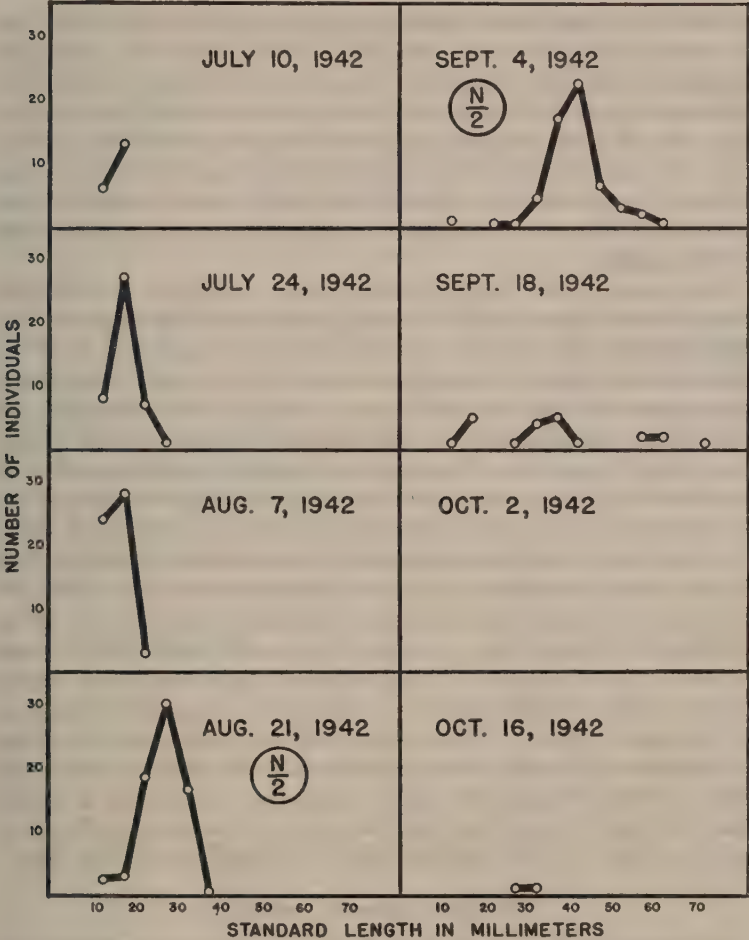


Figure 12. Length-frequency curves of *Spheroides maculatus*.

It is apparent from the length data that no individuals less than 11 mm. in length were taken in the Morris Cove collections during the summer and fall of 1942. Yet these small fish were consistently present until the middle of September—a fact which supports the published accounts of the considerably protracted spawning period cited above, since small individuals, which were apparently the

product of later and later spawnings, kept appearing in the shore zone all the time from July until early fall. On the other hand, the mean standard length, as well as the upper size limits were increasing in value steadily; in fact the growth increments at biweekly intervals, as judged by the mean lengths, appeared to be geometric in their progression. In any event two facts stand out—the number of individuals collected was successively greater from early June through August, and a rapid increase of the mean standard length was exhibited until mid-September.

Welsh and Breder (1922) studied certain aspects of the early life history of this species in New Jersey, and in their data they recorded approximately five days for incubation at a temperature of 67° F., and a larval period of 10 days, presumably at the same temperature. This temperature was reached in the vicinity of New Haven in early June, 1942. Inasmuch as the fish collected on July 10 were 15 mm. long, which is more than five times the length of the fish described by these authors at the emergence from the larval stage, it can be assumed that spawning took place either late in May, considering a longer incubation period at the temperature for that period, or early in June. Further, since the largest number of individuals was taken in the last of August, and since that collection still contained small fish of approximately the same size as those of the earlier collections, it seems to follow that the height of the protracted spawning period for the vicinity of New Haven harbor was early July, or possibly late June, in the season of 1942. In this connection it is important to note that no *Spheroides maculatus* were encountered in the May or June collections in 1943, although 0+ fish of this species were taken in July at Pine Orchard, Connecticut, in the course of another study; these agreed in size with the collections from Morris Cove of July 1942.

Microgadus tomcod (Walbaum)

Microgadus tomcod was one of the few species that exhibited distinct seasonal abundance in Morris Cove. Several individuals were taken in the fall of 1942, and it was present again only during May and June, 1943. On several occasions in the spring it was present in comparatively large numbers, and it ranked first in abundance once.

The first *M. tomcod* were taken on November 13, 1942, when two individuals 172 and 292 mm. in length were collected. Both were females with prominent ova, which, so far as could be determined

from an examination of the preserved specimens, were not yet fully developed. In mid-spring young *M. tomcod* appeared in the catch, 12 individuals being collected on May 14; these ranged from 16 to 31 mm. On May 28, 91 fish of this species were taken, and these ranged from 24 to 55 mm., the mean length for the collection being 36.1 mm. On June 11, 198 tomcod, ranging from 31 to 76 mm. were seined; this population had a mean length of 51.3 mm. Two weeks later only 20 *M. tomcod* were taken. Subsequent collections, made after the end of this study, failed to reveal *M. tomcod* in the region in early and mid-July, 1943.

M. tomcod ranked seventh in relative abundance of the species represented in the Morris Cove collections. On November 13 the two individuals taken ranked fifth in abundance, the collection containing only 285 fish divided among six species. On May 14, the tomcod ranked fourth, and on May 28, third. *M. tomcod* dominated the list on June 11, and was third again on June 25.

The appearance of relatively large individuals of this species in the Morris Cove area in the fall of 1942 corresponded with the movements associated with spawning, and it seems reasonable to suppose that the

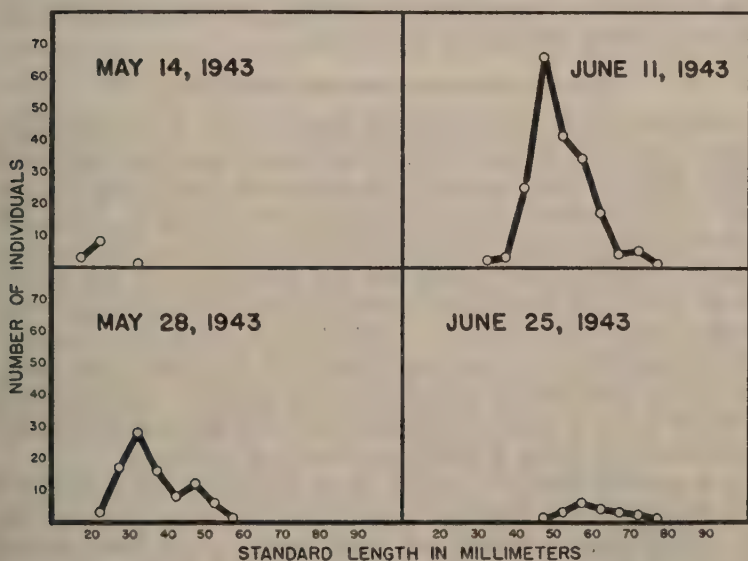


Figure 13. Length-frequency curves of *Microgadus tomcod*.

young that were present in the spring of 1943 were the result of a spawning in nearby waters. The rate of growth of these 0+ fish is indicated by the progression of the modes in Fig. 13 and the mean standard lengths in Table X. However, there is no positive assurance

TABLE X. NUMBER, LENGTH AND RANK OF ABUNDANCE OF
Microgadus tomcod

Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation	Rank
XI-13-42	2	172-292	.....	.....	5
V-14-43	12	16- 31	.....	.....	4
V-28-43	91	24- 55	36.1 $\pm$.714	6.82 $\pm$.505	3
VI-11-43	198	31- 76	51.3 $\pm$.540	7.65 $\pm$.384	1
VI-25-43	20	47- 75	.....	.....	3

that the young individuals represented in the spring collections were necessarily the product of the spawning of adult fish on or near the same date. The spawning period probably extends over several months, and the young fish taken in the spring could therefore differ considerably in age. That this situation obtained in the May 28 and June 11 collections is supported by the shape and extent of the length-frequency curves on those dates (Fig. 13).

Cynoscion regalis (Bloch and Schneider)

Cynoscion regalis was among the species which were consistently present, although not particularly abundant, during the summer of 1942. This fish first appeared in the collections from Morris Cove on July 24. It reached a peak of abundance on August 21, when 222 individuals were taken, and following this date the numbers declined sharply. Mid-October marked the last appearance of this species for the year in the Morris Cove collections, and it was not represented at all in 1943. Obviously, *C. regalis* did not rank high in terms of relative abundance. When first collected it was fourth, two weeks later it was sixth, and on August 21, it was second. On September 4 it was in the sixth place of abundance, and that date marked the last time that it was taken in sufficient numbers to be ranked.

It is probably true for *C. regalis*, as for many of the other species in this study, that the collection dates did not coincide precisely with the actual peaks of abundance. But on the other hand, general trends in abundance seem to be indicated clearly in many of the fishes

TABLE XI. NUMBER, LENGTH AND RANK OF ABUNDANCE OF
Cynoscion regalis

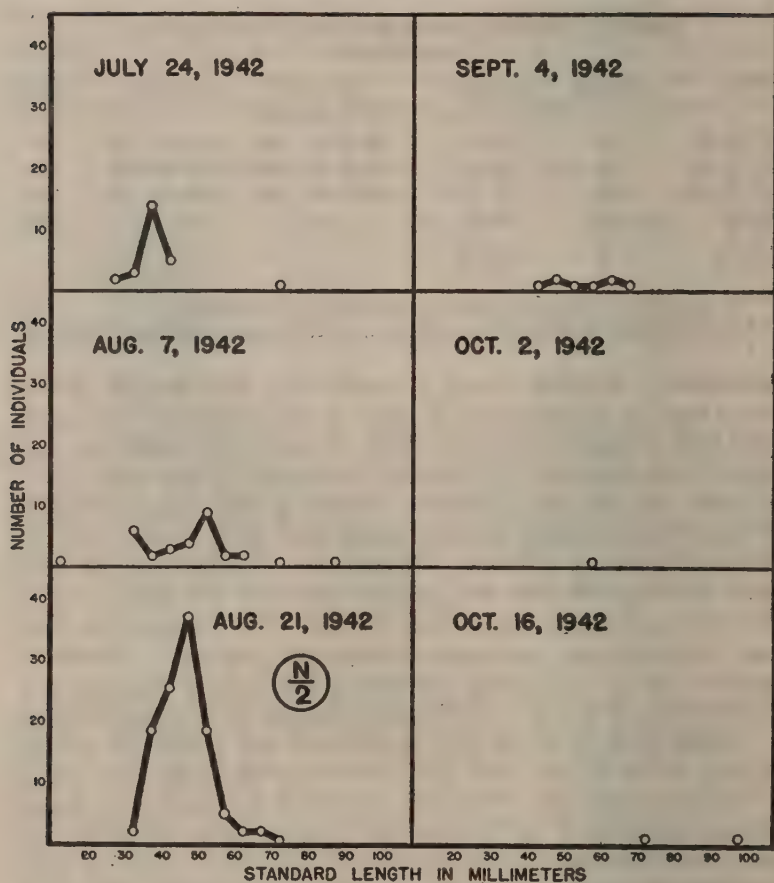
Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation	Rank
VII-24-42	25	25-70	36.8* $\pm$.84	4.15 $\pm$.46	4
VIII-7-42	31	14-89	46.6† $\pm$ 1.24	9.06 $\pm$ 1.36	6
VIII-21-42	222	30-73	46.2 $\pm$.16	2.38 $\pm$.11	2
IX-4-42	8	43-65	.....	.....	6
X-2-42	1	55	.....	.....	..
X-16-42	2	72-98	.....	.....	..

* One specimen, 70 mm., omitted from calculation of the mean.

† Three specimens, 14 mm., 71 mm., 89 mm., omitted from calculation of the mean.

encountered. Needless to say, *C. regalis* may have been in Morris Cove a week or so before July 24, when it was first taken. Of the 25 individuals encountered on this date, 24 were well within the size range of fish-of-the-year, but one was considerably larger than any of the other fish in that collection. Omitting this large individual (70 mm.), the remaining 24 had a spread from 25 to 44 mm., and the mean length for the collection was 36.8 mm. The next sample contained six more fish than the previous collection, but three of them were well separated in length from the rest. Two of these fish were large (71 and 89 mm.) and one was very small (14 mm.). The mean length of the 28 individuals constituting the bulk of the August 7 collection was 46.6 mm. The largest collection of *C. regalis* (August 21) ranged from 30 to 73 mm. in size and was distributed mainly between 30 and 60 mm., with a few additional fish at the upper limits of the spread (Fig. 14). That this population was reasonably homogeneous is evidenced by the fact that the variation coefficient (expressed as percentage of the standard deviation in the mean) was 5.16, compared with 11.27 on July 24, and 19.44 on August 7. The mean length of this collection was 46.2 mm. The next collection was taken on September 4, and contained but eight fish ranging from 43 to 65 mm. No more *C. regalis* were encountered until a month later, when one fish was collected; the two individuals taken on October 16 marked the last appearance of the species for the season.

The numbers of immature *C. regalis* in Morris Cove were considerably less than might have been expected from reports in the literature. Many investigators have encountered these fish in just such localities. Higgins and Pearson (1927) say they remain in the

Figure 14. Length-frequency curves of *Cynoscion regalis*.

sounds and bays as immature individuals, and Welsh and Breder (1923), Hildebrand and Cable (1934), Nesbit (1939), Greeley (1939), and Bigelow and Welsh (1925), all substantiate this view. Thus the impression is gained that they were more abundant in the localities referred to by these authors than in the area under consideration in this study. Apart from the fact that the collection dates may not have corresponded with the dates of actual abundance, as mentioned above, there are several possible explanations for the relatively few

weakfish collected in Morris Cove. For example, 1942 may not have been a good spawning year for this species. That great fluctuations in abundance of the young occur is well known; Sherwood and Edwards (1901) pointed to this and suggested a possible inverse relationship between the numbers of *C. regalis* and *Pomatomus saltatrix*. However, this relationship is now generally discounted (Bigelow and Welsh, 1925). Sherwood and Edwards (*loc. cit.*) also indicated local variations in abundance between Buzzards Bay and Narragansett Bay, and this points to the fact that New Haven Harbor may be sufficiently out of the range of this species to limit the number that would ever be taken from Morris Cove at one time.

The small numbers taken in 1942 do not shed much light on the population analysis of this species, and any inferences are questionable. On the basis of the limited evidence available, it appears that new populations of *C. regalis* came into the area throughout the season, as in previously discussed species. Almost all the collections contained fish-of-the-year, and the sizes agree generally with the observations of other authors. Sherwood and Edwards (1901) cite measurements that are in essential agreement with the present observations; Perlmutter (1939) lists 40 to 44 mm. as the size of the fish taken in July and August; on the other hand, Tracy (1910) encountered larger specimens in August. If Hildebrand and Cable (1934) are correct in their assumption that weakfish less than 10 mm. in length are the product of nearby spawnings, then some of the individuals encountered in Morris Cove probably were produced in regions close at hand. However, Welsh and Breder (1923) think that the eggs and larvae are carried by currents and sink only during later stages of development. Thus many of these fish may well have been spawned at more distant places. But it is difficult to believe that a specimen as small as 14 mm. taken in August could have been spawned far from the scene of the study.

The few larger individuals encountered in the earlier collections allow room for various speculations as to their origin. These fish may have been representatives of the upper size limits of this species which were in the area on that date, and the seine may have failed to sample the population adequately. They may also have been the result of an early spawning either in nearby waters or in more southerly waters. That they were fish-of-the-year seems reasonable in view of the generally-accepted fact that second-year weakfish remain in more southern regions.

Scophthalmus aquosus (Mitchill)

Scophthalmus aquosus, the windowpane or daylight flounder, one of the common residents of Long Island Sound, was encountered occasionally in the course of the Morris Cove study. It never was plentiful, and occupied ninth place in rank of abundance for the year in conjunction with *Menticirrhus saxatilis*. It is given preference over *M. saxatilis* because *S. aquosus*, when it was present, more nearly dominated the population in numbers. Comparison of the respective ranks of abundance indicated in Tables XII and XIII shows that *S. aquosus* ranked second, third, and fourth on those dates when it could be ranked, while *M. saxatilis* never achieved better than sixth place.

S. aquosus only ranked high in the scale of relative abundance in April and early May, when very few fish of any species were present in the area. It ranked second on April 16, and third on April 30, but in late May, when the largest collection of this species was made, it ranked fourth, *Clupea harengus*, *Syngnathus fuscus*, and *Microgadus tomcod* exceeding it in numbers.

Nichols and Breder (1926), Tracy (1910), and other authors place the spawning period of this species in May and June. But if reproduction is confined to these months in Long Island Sound, then the smaller fish taken at Morris Cove in the course of the present study are extremely difficult to explain on the basis of length alone. The individuals taken in August and October (85 and 80 mm. respectively) would either have to be fish-of-the-year which grew remarkably fast, or 1+ fish which grew rather slowly. The 49 mm. specimen taken in late April, as well as the majority of the 45 *S. aquosus* in the collection of late May, would have to be fish which were approximately a year old; this would indicate an almost inconceivably slow growth rate and would be difficult to reconcile with statements by Tracy (1910) and Bigelow and Welsh (1925) to the effect that growth in the early stages of development is rapid. Similarly the 88 mm. specimen of June 25 would have to be an incredibly fast-growing 0+ fish, or a surprisingly small one-year-old.

The present authors, from observations on the commercial trawlers operating out of Connecticut ports in 1943, incline to the belief that spawning in this region may possibly begin as early as May, reaches a peak in June and July, and continues at least into August. Although it is obviously impossible to draw well-substantiated conclusions from

TABLE XII. NUMBER, LENGTH, AND RANK OF ABUNDANCE OF
Scophthalmus aquosus

Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation	Rank
VIII-21-42	1	85	.....	.....	..
X-2-42	1	80	.....	.....	..
XI-13-42	1	211	.....	.....	..
IV-16-43	2	204-231	.....	.....	2
IV-30-43	3	49-212	.....	.....	3
V-28-43	45	35-73	51.1 $\pm$ 1.23	8.25 $\pm$.87	4
VI-25-43	1	88	.....	.....	..

the exceedingly limited data at hand, the sizes of the small *S. aquosus* in the Morris Cove collections fit the conception of summer spawning far better than that of reproduction in the spring. Under these conditions the August and October fish, 85 and 80 mm. long, would quite certainly be in the 1+ group; the 49 mm. individual taken in April as well as the majority, if not all of the collection of May 28 (mean length 51.1 mm.), would definitely be fish approaching the completion of their first year of life; and the 88 mm. specimen of June 25 would either be a rather large fish approximately one year old, or a slow-growing *S. aquosus* nearing or at the completion of its second year. If the above assumptions concerning age are correct, an adjustment of previously conceived ideas regarding the time and length of the spawning period is clearly in order. It should be mentioned that not only may the spawning period extend over a much greater period and occur later in the summer than has heretofore been recognized, but there may well be distinct races of this species, as suggested for *Pseudopleuronectes americanus*, which spawn at different times.

The larger fish taken in this study are not easy to account for in water as shallow as that of the Morris Cove area, although it is recorded by Nichols and Breder (1926) that this species is sometimes found stranded on beaches by falling tides. But the consensus of opinion seems to be that they inhabit deeper water as a rule. It seems possible that they approach the shore in the pre-spawning period. The large fish, encountered late in the winter and spring, may indicate an on-shore movement of adults in the colder months.

Menticirrhus saxatilis (Bloch and Schneider)

The northern kingfish was among the species taken consistently although never in large numbers through the summer of 1942 at Morris Cove. It was collected from July 10 through October 2, 1942, with a single interruption in late September. This species tied with *Scophthalmus aquosus* for the ninth place of abundance, but never achieved a rank higher than sixth place on any collecting date.

The *M. saxatilis* taken on the Morris Cove beach were, without exception, small and it seems entirely probable that these were all fish-of-the-year if Nichols and Breder (1926) are correct in their statements regarding growth. Most authorities agree that spawning takes place mainly in June and early July, although Welsh and Breder

TABLE XIII. NUMBER, LENGTH, AND RANK OF ABUNDANCE OF
Menticirrhus saxatilis

Date	Number	Size Range (S.L. in mm.)	Rank
VII-10-42	14	13-26	6
VII-24-42	13	17-49	6
VIII-7-42	10	42-78	8
VIII-21-42	17	27-90	8
IX-4-42	7	21-87	7
X-2-42	7	59-90	7

(1923) state that it continues until August. The collection of the smaller individuals in early September seems to point to a spawning date later than mid-July in 1942, although the material available for study is not sufficient to justify general conclusions.

The first collection, taken July 10, 1942, contained 14 fish that ranged in size from 12 to 26 mm., and the species ranked sixth in abundance on that date. Two weeks later 13 individuals were taken, and the size range was different in that the upper limit was considerably higher than that of the previous collection, and the lower limit only slightly so. However, most of the individuals of the collection fell around the 20 mm. mode, and only three were in the 40 to 49 mm. length interval. *M. saxatilis* ranked sixth on that date. The third collection (August 7) contained 10 fish that were comparatively large, ranging from 42 to 78 mm., with five of them falling in the 50 to 59 mm. length interval. The rank of abundance fell to eighth place.

The collections taken in late August and early September contained

individuals which were smaller than those taken in early August and which apparently represented new populations that had come into the area. The large collection taken August 21 had two individuals in the 27 to 29 mm. length interval, two in the 30 to 39 mm. interval, and four in the 40 to 49 mm. interval. Others, presumably the product of earlier spawnings, were present in the 50 to 59 mm., 60 to 69 mm., and 80 to 89 mm. intervals. With the exception of the fish in the 50 to 59 mm. category, the larger individuals probably represented fish of the populations taken previously. But the smaller fish were apparently younger, probably resulting from an early August spawning. The same assumption seems reasonable for most of the collection taken September 4 although the lone 21 mm. fish might have been stunted. For if a mean length of 19 mm. (computed for the population of July 10, 1942) was attained in the period from early June to July 10, similar or slightly larger fish taken in early September in all probability would have been born in August, especially since the higher temperatures of summer should make for faster development.

The last collection was taken on October 2 and contained seven individuals that were comparatively large, ranging from 59 to 90 mm. Most authorities agree that this species leaves the vicinity of southern New England in October, and it is probable that the smaller fish which inhabit the shore zone would leave that area a little earlier, and after a period of life spent further from shore, move southward.

Clupea harengus Linnaeus

The common herring was encountered three times in the course of this study. All of these collections were in the spring of 1943, and twice this species dominated the fish population in the area. All specimens were small, many of them being but little advanced from the larval stage.

The first collection that contained *C. harengus* was on April 30, when one postlarval individual 34 mm. long was taken. The next collection, May 14, contained 464 *C. harengus* ranging from 33 to 54 mm. in length, with a mean at 42.4 mm. Of this collection 100 individuals were so different in external appearance from the other specimens taken at the same time that they were designated as "postlarval" stages. The rest of the collection, 364 fish, were older and were designated as "juveniles." It seems probable that two broods were

taken at this time, although this is not indicated in Fig. 15, where examination of the curve suggests an apparently false homogeneity owing to the overlap in lengths of the postlarval and small juvenile fish. Two weeks later 431 specimens were collected, all having the characteristics of juvenile fish and ranging in length from 34 to 63 mm., with a mean for the collection of 41.2 mm.

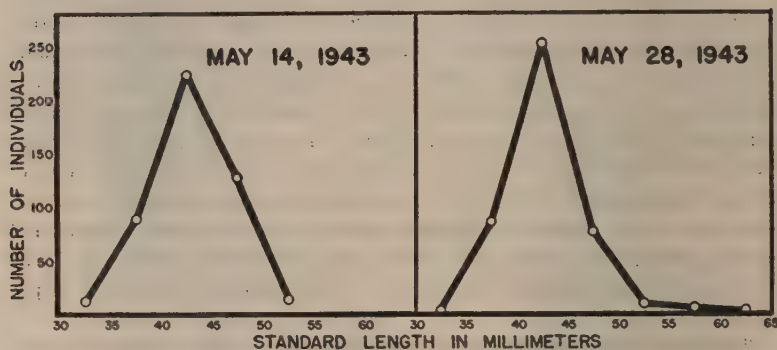


Figure 15. Length-frequency curves of *Clupea harengus*.

TABLE XIV. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Clupea harengus*

Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation	Rank
IV-30-43	1	34	.....	.....	..
V-14-43	464	33-54	42.4 $\pm$.174	3.74 $\pm$.123	1
V-28-43	431	34-63	41.2 $\pm$.170	3.49 $\pm$.119	1

The entire collections of May 14 and May 28 were dominated by *C. harengus* and this species ranked first in abundance on these dates. *C. harengus* ranked eleventh in relative abundance for the entire year.

The presence of these small individuals corroborates the statements of Bigelow and Welsh (1925), who say that "—west of Cape Cod the herring do not begin to spawn until mid- or late October, with the major production of eggs about the 1st of November." The winter growth rates observed by others in southern New England, when applied to the small herring encountered in this study, would indicate a late fall or early winter spawning. It is also probable that the highly limited seasonal appearance of herring in this biotope as shown in this study is characteristic.

Myoxocephalus aeneus (Mitchill)

Of the various species in the genus *Myoxocephalus* listed for the Long Island Sound region, there are two which, when they have been given separate specific rank, have not been easily distinguishable. According to Nichols and Breder (1926) one, *M. aeneus*, is supposed to be common; the other, *M. mitchilli*, is supposed to be rare, but is occasionally mentioned in the literature. The exact distribution of these two species and their identity has been the subject of considerable confusion—e. g., Greeley (1939) considered that all of the sculpins in his collection were *M. mitchilli*, while Perlmutter, in the same report (1939) identified all his specimens as *M. aeneus*.

The fish in the present collection were examined and measured by Mr. Willard D. Hartman, a student at Yale University, who in the course of his work discovered that all the specimens identified as *M. aeneus* were females, and the *M. mitchilli* males. This obviously indicated that these fish were identical as to species. Mr. Hartman, who has pursued this study further and has examined other collections (Hartman, MS.) has supplied the following brief discussion of the situation in regard to the Morris Cove specimens:

"Examination of 34 specimens of the *Myoxocephalus* which were taken during the course of the study of the fishes of Morris Cove, suggests the synonymy of the two species, *M. aeneus* and *M. mitchilli*. Of the total number caught, 31 were females, as was revealed by examination of their gonads. These specimens corresponded fully to the usual descriptions of *M. aeneus*, i. e., they had a "brassy" color and generally had three indistinct bars across their ventral fins. These bars were entirely absent in young specimens (circa 50 mm.), and one or two of the bars were sometimes either absent or represented only by small spots on the fin rays in the adult females. The remaining three specimens caught on the regular biweekly Morris Cove trips were males. Two of these specimens were young, measuring 53 and 60 mm. standard length and being only slightly darker in color than the average female. The ventral-fin bars were not conspicuous, but were more clearly defined than in females of corresponding sizes. The third specimen measured 73 mm. Its color was darker than that of the average female, and it had three distinct ventral-fin bars which were more clearly defined than on any female in the collection. Two adult

male specimens, 85 and 82 mm. standard length, were caught in New Haven harbor on occasions other than the regular Morris Cove trips. These clearly answered the description usually given for *M. mitchilli*, i. e., they were darker, nearly black, in general body color, and they possessed four clearly outlined bars on the ventral fins. On the basis of the limited amount of material in this collection, the most logical conclusion is that the two supposed species are males and females of the same form."

TABLE XV. NUMBER, LENGTH AND RANK OF ABUNDANCE OF
Myoxocephalus aeneus

Date	Number	Size Range (S.L. in mm.)	Rank
VII-10-42	1	68	..
VII-24-42	2	67-124	..
VIII-21-42	2	65- 83	..
IX-18-42	1	178	..
X-16-42	15	53-116	6
X-30-42	1	53	..
XI-13-42	9	64-111	2
V-14-43	1	65	..
V-28-43	1	82	..
VI-25-43	1	112	..

The first *Myoxocephalus aeneus* was taken on July 10, 1942, and was a female. On July 24 two more females were taken, two were collected on August 21, and another was taken September 18. On October 16 the largest collection of this genus was made; all were females except one. This collection ranged from 53 to 116 mm. in length and ranked sixth in abundance. A single female was also taken on October 30, and 9 individuals were netted on November 13, two of which were males. This last collection ranked second in abundance. This fish did not appear again until May 14, 1943, when a female 65 mm. long was collected. On May 28 and June 25 single females, 82 and 112 mm. long respectively, were secured.

That these fish are permanent residents of the region seems to be indicated by the fact that they were taken pretty generally throughout the entire course of the study, except in the extremely cold months of the winter. They appeared to be more abundant near the tide line of the sandy beach during the fall, but the numbers taken were so small that it is doubtful that they are ever plentiful on a sandy

bottom. The heavy preponderance of females in this species seems unusual and is worthy of further investigation.

Pomatomus saltatrix (Linnaeus)

The bluefish, *Pomatomus saltatrix*, was taken in Morris Cove in October 1942 on two occasions. This species, the young of which are very common on the southern New England coast during the fall in most years, was not encountered in the area at any other time in the course of this study, although of course it may have been present at intervals between the regular collections.

TABLE XVI. NUMBER, LENGTH, AND RANK OF ABUNDANCE OF
Pomatomus saltatrix

Date	Number	Size Range (S.L. in mm.)	Rank
X-2-42	9	80- 97	6
X-16-42	6	86-118	7

It ranked sixth and seventh on the dates when it was captured, but collections made in 1943 for other purposes indicated that during that year it was probably more abundant than in 1942. In general, collections made outside New Haven Harbor seem to contain more small bluefish than those taken inside; this would point to the assumption that a more open environment is preferred, but Perlmutter (1939) and others have found many young bluefish in bays. The fact that the bluefish is such an active animal may also account for the few captures in this work.

The absence of smaller bluefish, 50 to 70 mm. in length, is possibly an indication that the Morris Cove area is not a favorable environment for this species, but it might also be argued from this inadequate evidence either that 1942 was a poor spawning year, or that the areas where reproduction takes place are sufficiently far removed so that the smaller fish do not often stray as far west on the north side of Long Island Sound.

Prionotus evolans evolans (Linnaeus)

Two species of the genus *Prionotus* were collected in the summer of 1942, *Prionotus evolans evolans* and *Prionotus carolinus*. Of these *P. evolans* was the more common, *P. carolinus* being taken only once.

P. evolans evolans was one of the minor species in the collections from Morris Cove, and was taken only in the months of August and September. The first lot was secured on August 7 and contained 28 fish, ranging in size from 23 to 51 mm. The mean length of this population was 36.1 mm. The next collection, taken on August 21, consisted of 59 individuals which ranged in standard length from 34 to 66 mm. and had a mean length of 46.2 mm. On the next two collecting dates a total of five fish were obtained; the lone individual taken September 4 was 89 mm. long and the four taken two weeks later ranged from 54 to 88 mm.

TABLE XVII. NUMBER, LENGTH AND RANK OF ABUNDANCE OF
Prionotus evolans

Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation	Rank
VIII-7-42	28	23-51	36.1 $\pm$ 1.26	6.65 $\pm$.889	7
VIII-21-42	59	34-66	46.2 $\pm$ 1.11	8.55 $\pm$.809	7
IX-4-42	1	89	.....	.....	..
IX-18-42	4	54-88	.....	.....	..

All of the individuals comprising the collections were small, and it seems reasonable to suppose that they were fish-of-the-year which were the product of a June or early July spawning. The means of the collections in August are probably a rough measure of the general order of growth at that season.

Anchoa mitchilli (Cuvier and Valenciennes)

The common anchovy was present in Morris Cove during the summer of 1942, and a single individual was collected in May of the succeeding year, but it was not common enough to have a designated rank of abundance in any of the biweekly collections except that of August 7.

The first collection of *A. mitchilli* was taken July 24, when a single individual was collected. The next was taken August 7 and consisted of 39 individuals, ranging from 25 to 36 mm., having a mean of 28.8 mm., and being fifth in abundance among the species collected on that date. The collections of August 21 had three anchovies with standard lengths of 25, 27, and 34 mm. The last collection for the summer season was taken on September 4, when a single individual 22 mm. long was secured. Another anchovy was collected on May

14, 1943; it was smaller than any caught previously, but was so damaged that measurements could not be taken.

Spawning in this species is supposed to take place in July and August, and it seems reasonable, judging by the size of the fish, to assume that the specimens in the first two collections (Table XVIII)

TABLE XVIII. NUMBER, LENGTH AND RANK OF ABUNDANCE OF
Anchoa mitchilli

Date	Number	Size Range (S.L. in mm.)	Mean Size (S.L. in mm.)	Deviation	Rank
VII-24-42	1	26	.....	.....	..
VIII-7-42	39	25-36	28.8 ± .413	2.58 ± .292	5
VIII-21-42	3	25-34	.....	.....	..
IX-4-42	1	22	.....	.....	..
V-14-43	1	....	.....	.....	..

were the result of July reproduction. The individuals taken in late August and early September were apparently the product of later breeding activity, while the small fish caught in May 1943 was in all probability an individual which had been born at the conclusion of the 1942 spawning season.

In many parts of Long Island Sound and adjacent waters this species is generally regarded as abundant. Greeley (1939), Perlmutter (1939), Tracy (1910), and Smith (1898), considered it common in parts of the region they studied, but Nichols and Breder (1926) point out that it is less numerous "to the westward," presumably meaning the approaches to New York.

Bairdiella chrysura (Lacépède)

In the late summer and early fall a few specimens of the silver perch, *Bairdiella chrysura*, came into Morris Cove. On August 21 this species ranked ninth in abundance and in mid-September it ranked seventh. The individuals in the collections were small, and if the assumptions of numerous other workers are correct they were all fish-of-the-year. They did not exceed the sizes indicated by Welsh and Breder (1923), Hildebrand and Schroeder (1928), and Perlmutter (1939), for fish in their first season.

It would be interesting to discover where these specimens were born, *i. e.*, whether they were the product of local or more southern spawning. The northernmost record of spawning is furnished by the

TABLE XIX. NUMBER, LENGTH AND RANK OF ABUNDANCE OF
Bairdiella chrysura

Date	Number	Size Range (S.L. in mm.)	Rank
VIII-21-42	11	19-31	9
IX-18-42	8	18-48	7
X-2-42	2	33-47	..
X-16-42	1	39	..

egg collection made by Perlmutter (1939) on the south shore of Long Island. Tracy (1910) first reported juveniles of this species from near Wickford, Rhode Island, but his collection was in the same category as the one from Morris Cove since a few individuals were taken in a shore seine and no further data is available.

Tautoga onitis Linnaeus

The tautog or blackfish, *Tautoga onitis*, was one of the minor species taken in the late summer and early autumn months of 1942. It was never abundant, not over five specimens being taken at one time, the highest rank achieved being eighth on two occasions.

TABLE XX. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Tautoga onitis*

Date	Number	Size Range (S.L. in mm.)	Rank
VIII-21-42	2	18-48	..
IX-4-42	2	50-61	..
IX-18-42	5	32-51	8
X-2-42	4	31-60	8
X-16-42	1	42	..

Apparently these collections were composed of fish-of-the-year, and the small numbers are probably best explained by the fact that the sandy beach is not a preferred habitat. Baird (1855) reported taking large numbers of small individuals in rivers and inlets of the New Jersey and Long Island coasts when hauling nets; T. H. Bean (1888) concurred with observations made at the same locality in New Jersey. Smith (1898) cited the species as being abundant everywhere on rocky bottom, and in this Bigelow and Welsh (1925), Nichols and Breder (1926), Tracy (1910), and others agree. Therefore it would seem that the fish taken in Morris Cove were either stragglers from more desirable habitats nearby or possibly young-of-the-year that had

not become acclimated to the more common rocky bottom environment.

Synodus foetens (Linnaeus)

In August and September the lizard fish, *Synodus foetens*, appeared three times in the collections, and in early September the species ranked eighth in abundance. Various authorities, Smith (1898), Bean (1888), and Tracy (1910) report it as being consistently taken but never in great numbers. The specimens collected in this study were small. Although little or nothing is known of the spawning habits, age at maturity, etc., of this species, the evidence from Breder (1944) points to an extended reproductive period. In view of this fact, as well as the voracious feeding habits and presumably fast growth rate, it seems probable that all the specimens in this collection were fish-of-the-year, with the possible exception of the largest individual—that taken on September 18.

TABLE XXI. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Synodus foetens*

Date	Number	Size Range (S.L. in mm.)	Rank
VIII-7-42	1	55	..
IX-4-42	6	63- 78	8
IX-18-42	1	107	..

The Less Abundant Species

In addition to the species discussed previously, there were 13 other kinds of fishes taken at Morris Cove which were much less abundant. Some of these were sporadic strays which are relatively uncommon in this region because it lies near the periphery of their known geographical distribution. Others were forms which are normal inhabitants of shallow-water sandy-beach areas but are never particularly abundant. And some were types which are more commonly found in other environments of the shore zone, but occasionally move onto different grounds. A further reason for the scarcity of some of the species probably lies in low productivity in one breeding season as opposed to another and in the vagaries of the distribution of pelagic eggs and larvae by different currents in succeeding years—*i. e.*, factors which cause fluctuations in abundance over the whole or any part of the range of the species under consideration. Finally, it should be mentioned that some fish which normally occur in habitats such as the

Morris Cove area were not taken in the course of this study; the reasons for their absence in the collections are not readily apparent.

TABLE XXII. NUMBER AND RANGE OF STANDARD LENGTHS OF THE
LESS ABUNDANT SPECIES

Species	Date	Number	Size Range (S.L. in mm.)
<i>Apeltes quadracus</i>	IX-18-42	4	32-41
<i>Pungitius pungitius</i>	VII-10-42	1	24
<i>Caranx hippos</i>	VIII-7-42	4	34-39
	VIII-21-42	1	42
<i>Leiostomus xanthurus</i>	VII-10-42	1	31
<i>Tautogolabrus adspersus</i>	VIII-21-42	1	21
<i>Opsanus tau</i>	VIII-21-42	1	58
<i>Urophycis tenuis</i>	IV-30-43	1	57
<i>Urophycis regius</i>	VI-11-43	1	45
<i>Pomolobus pseudoharengus</i>	VIII-7-42	1	27
<i>Osmerus mordax</i>	V-14-43	4	60-79
<i>Pollachius virens</i>	IV-16-43	2	24-27
	V-14-43	1	23
<i>Prionotus carolinus</i>	VII-10-42	1	134
<i>Anguilla rostrata</i>	(Taken fairly regularly throughout the collecting season.)		

The sticklebacks, *Pungitius pungitius* and *Apeltes quadracus*, and possibly the jack, *Caranx hippos*, were in all probability strays from habitats with more abundant vegetation; this can also be said of the spot, *Leiostomus xanthurus*, if the data of Hildebrand and Cable (1930) are applicable to Long Island Sound. Both *C. hippos* and *L. xanthurus* approach the northern limits of their ranges in southern New England and therefore would not be expected to be as plentiful as further to the south. *Tautogolabrus adspersus* and *Opsanus tau* were apparently wanderers from rocky habitats where they are well known, although they have been reported from sandy or muddy bottoms occasionally. The hakes, *Urophycis tenuis* and *regius*, were also presumably strays from other environments and it is not easy to account for their presence in the shallow water of the sandy beach. Some difference of opinion is expressed in the literature concerning the habits of the young *U. tenuis*, but that they have been found frequently associated with floating vegetation seems agreed upon by Bigelow and Welsh (1925) and Nichols and Breder (1926). Young *U. regius*, according to Nichols and Breder (*loc. cit.*), are to be found

"on the bottoms of rather deep, muddy bays." The single alewife, *Pomolobus pseudoharengus*, and the four smelt, *Osmerus mordax*, were almost unquestionably the product of spawning in nearby fresh or brackish water. Since they are both well known from the region, it is difficult to explain their near absence in the biweekly samples from Morris Cove. The two collections of pollack, *Pollachias virens*, both taken in the spring, form examples of a species nearing the southern limits of its geographical range. These fish, the product of spawning in late 1942, probably were carried toward the vicinity by currents, since it is doubtful if spawning takes place "west of Cape Cod," according to Bigelow and Welsh (1925). *Prionotus carolinus* apparently prefers the sandy habitat as an adult, and it is possible that the young may be present there also. The single specimen collected in mid-summer indicates that they are to be found in Morris Cove, but their apparent rarity is peculiar in view of statements by Nichols and Breder (1926) regarding their abundance, as well as the relatively large numbers of *P. evolans evolans* which were taken in this study. Finally, the common eel, *Anguilla rostrata*, was encountered in a number of the spring, summer, and fall collections, although seldom more than a single individual or two were taken on one date. Unfortunately they were discarded in the early part of the study, and inasmuch as the record was incomplete they were merely noted subsequently. Although they were fairly consistently present they were among the less abundant species.

PHYSICAL ASPECTS OF THE ENVIRONMENT

Reference to the field data, with respect to such physical factors as were noted in connection with the Morris Cove biweekly collections, indicates some interesting trends that are important in the analysis of the fish population of the area under consideration. Although the data and general observations were for the most part rough and not entirely consistent, the information shows relationships that seem significant.

Temperature

Water temperatures ranged from 26.8° C. in late August to subzero in late December. No consistent and measurable stratification existed in the shallow water of the shore zone at Morris Cove, so that near-surface readings were indicative of conditions throughout the area. Ice

was formed in late December and continued through February, except for a thaw which was produced by rain on February 5, 1943. The general ascending and descending seasonal trends of heat acquisition and loss were fairly regular, and only comparatively minor variations appeared in the summer and winter periods of relatively constant temperature (Fig. 16).

From the standpoint of this study, there were definite relationships not only between the temperature and the population of fishes as a whole, but also between temperature and the various component species. These are presented below, but it should be borne in mind also that the individual fish within each species were probably affected by temperature in a manner so subtle that clear-cut correlations could not be detected from rough data of the type collected in this study. Therefore the relationships here presented concern only the total population and the component species, both of which were affected profoundly by temperatures and reacted in a fairly definite manner. These reactions obviously concern definite sizes and age categories in some species—notably the young and immature, while in others they involve a wide range of size and age-groups.

The most obvious relationship between temperature and the population at the Morris Cove shore zone is the fact that during the winter months, beginning in December and continuing through to mid-April, no fish were taken except for a lone *Fundulus majalis* on March 19, 1943. During this period the temperatures ranged from 4.2° C. on December 11, 1942, downward to -0.4° C. on December 24, and up to 6.2° C. on April 16, 1943, when the first collection that contained more than a single fish was made. As the temperatures rose in the spring a greater variety of fishes appeared in the area, six species being taken on April 16, 1943, as compared with 17 taken on August 21, 1942 (Fig. 17). As the temperatures descended in the late summer and fall the variety of species decreased until December 11, 1942, when only three species were present. After that no fish were taken in the area until spring, despite the fact that full normal effort to secure them was made. This tendency to increase in variety as the summer season progressed has been noted before. Thus Greeley (1939) mentioned it as a "well known" fact, but his data covered only the summer months and he qualified his statement by saying that if collections could be continued into the fall a downward trend might be proven. The close parallelism between the two factors shown in Fig. 17 substantiates this view.

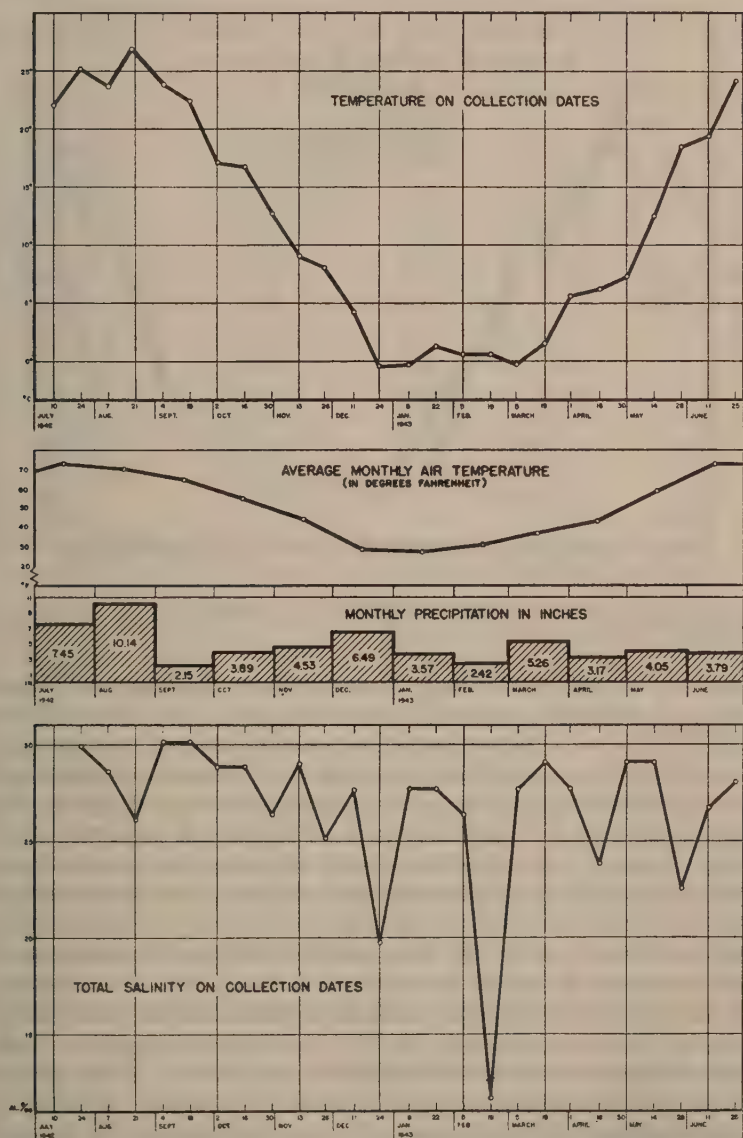


Figure 16. Water temperature and total salinity estimates on the days collections were made, compared with air temperatures and precipitation data from records of the United States Weather Bureau.

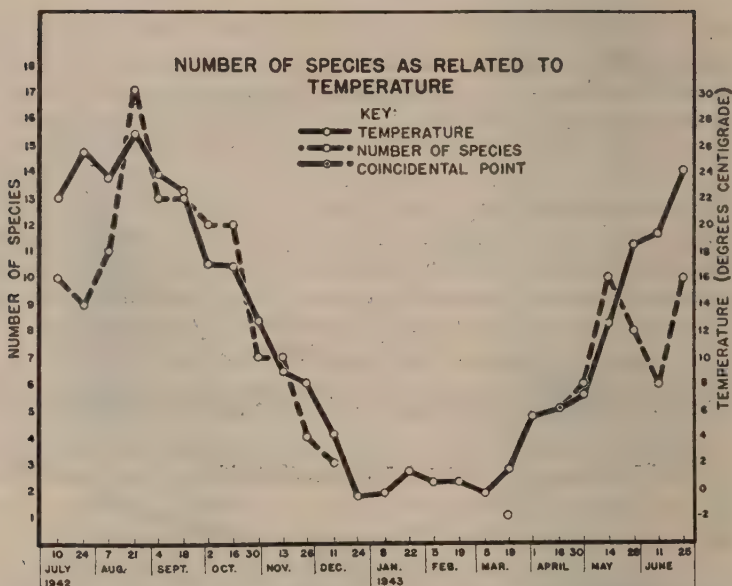


Figure 17. The variety of species as related to the temperature of the water on the collection dates.

Turning to the relationship of temperature and the individual species, the limits are indicated in a general way by the data in Table XXIII. However, the maximum temperatures are in no way accurate indicators of the upper limits, since 26.8° C. was the highest level reached, and there is no reason to suppose that some of the species concerned would not have remained in the area if the water had become warmer. On the other hand, the minimum temperatures probably give a fairly good indication of the lower limits for the different sizes of the species of this biotope, since the water temperature went considerably below the level at which all the fish disappeared from the area. It should be emphasized, then, that the maximum and minimum temperatures as listed in Table XXIII are nothing more than broad estimates of the limits within which the individuals of the size here encountered will remain in this biotope. That certain species exhibited variations from the trend of increasing variety with increasing temperature is apparent from consideration of the data in Table XXIII. Thus *Microgadus tomcod* and *Clupea harengus* were

TABLE XXIII. MAXIMUM AND MINIMUM TEMPERATURES ENCOUNTERED BY THE MORE ABUNDANT SPECIES

Species	Date	Maximum Water Temp. in °C.	Date	Minimum Water Temp. in °C.
<i>M. m. notata</i>	VIII-21-42	26.8	XII-11-42	4.2
<i>P. americanus</i>	VIII-21-42	26.8	XII-11-42	4.2
<i>S. fuscus</i>	VIII-21-42	26.8	IV-16-43	6.2
<i>Fundulus</i> spp.	VIII-21-42	26.8	XII-11-42	4.2
<i>B. tyrannus</i>	IX-4-42	23.9	XI-26-42	8.1
<i>S. maculatus</i>	VIII-21-42	26.8	X-16-42	16.6
<i>M. tomcod</i>	VI-25-43	24.1	XI-13-42	9.1
<i>C. regalis</i>	VIII-21-42	26.8	X-16-42	16.6
<i>S. aquosus</i>	VIII-21-42	26.8	IV-16-43	6.2
<i>M. saxatilis</i>	VIII-21-42	26.8	X-2-42	17.1
<i>C. harengus</i>	V-28-43	18.4	IV-30-43	7.3
<i>M. aeneus</i>	VIII-21-42	26.8	XI-13-42	9.1
<i>P. saltatrix</i>	X-2-42	17.1	X-16-42	16.6
<i>P. evolans evolans</i>	VIII-21-42	26.8	IX-18-42	22.3
<i>A. mitchilli</i>	VIII-21-42	26.8	V-14-43	12.5
<i>B. chrysura</i>	VIII-21-42	26.8	X-16-42	16.6
<i>T. onitis</i>	VIII-21-42	26.8	X-16-42	16.6
<i>S. foetens</i>	IX-4-42	23.9	IX-18-42	22.3

important components of the spring population when the temperatures were ascending, but were gone from the area before the peak of variety was reached. Similarly, the adults of *Syngnathus fuscus* left the area before the highest temperature was recorded, although the immature forms were collected regularly thereafter. Certain minor species also appeared at times other than at the height of the summer season, but these were apparently stragglers from other habitats.

The reactions of individual fish of the different species to temperature were not apparent from this study, although some evidence regarding the relation of numbers and season is forthcoming. Since the temperatures recorded for Morris Cove also applied in a general way to a large expanse of adjacent water, it follows that the fish were not limited to the area which was seined by the heat factor alone. As might be expected, therefore, the number of individuals did not show a regular increase with temperature, either in the aggregate for all species or for any particular species. Obviously there were more fish in this area in the warmer months as mentioned above, but beyond this broad generalization there appears to be no direct correlation with temperature. The peaks of total abundance and the

fluctuations in numbers of individuals by collection dates (Fig. 20) show no clear trend, although it is true that near the lower limits of the temperature curve the number of individuals of the species that were present was less, and the collections were small.

Salinity

The salinity varied from $30.2^{\circ}/_{\infty}$ in September to $11.6^{\circ}/_{\infty}$ in February. Reference to Fig. 16 indicates that generally the total salt concentration was conditioned by the precipitation, that the trend in late summer and early fall was downward, and that after the extreme low encountered in late winter the spring samples showed relatively rapid fluctuations between 22.5 and $29.1^{\circ}/_{\infty}$.

No direct evidence is apparent from this data as to the effect of total salinity on the populations of fishes taken in Morris Cove, although the downward trend in the fall more or less followed the decline in temperature and variety of species discussed above. But the fluctuations in salinity from one date to another over the line of general trend were so marked that it is doubtful if total salinity was a limiting factor, either for species or numbers of individuals.

The range of total salinity during the period when the fishes were present in the area was from $22.5^{\circ}/_{\infty}$ to $30.18^{\circ}/_{\infty}$, a difference of $7.7^{\circ}/_{\infty}$, and the mean of the salinity readings for the same period was $27.7^{\circ}/_{\infty}$. Most of the species collected from the shore zone were unquestionably euryhaline forms. However, the limits of salinity were rather narrow during the time when some species were present. This was especially true for the immature forms of some of the migrants from the south, although the data collected from Morris Cove do not permit definite conclusions. Table XXIV shows the extremes of total salinity encountered by each of the more abundant species as well as the differences between the maxima and minima.

Light

Light conditions within the area were manifest both in the condition of the sky and the water. The condition of the sky was recorded but showed no direct relationship with the numbers of fish taken. Considering the three most abundant collections, one (September 18) was taken on a cloudy day, one (July 10) on a hazy day, and one (October 30) on a clear day. And one of the less abundant collections (October 2) was taken on a clear day.

TABLE XXIV. THE MINIMUM AND MAXIMUM TOTAL SALT CONCENTRATIONS (‰) ENCOUNTERED BY THE MORE ABUNDANT SPECIES

Species	Date	Highest Salinity	Date	Lowest Salinity	Difference between extreme salinities
<i>M. m. notata</i>	IX-4-42	30.2	V-28-43	22.5	7.7
	IX-18-42	....	....	....	..
<i>P. americanus</i>	IX-4-42	30.2	V-28-43	22.5	7.7
	IX-18-42	....	....	....	..
<i>S. fuscus</i>	IX-4-42	30.2	V-28-43	22.5	7.7
	IX-18-42	....	....	....	..
<i>Fundulus</i> spp.	IX-4-42	30.2	XI-26-42	25.1	5.1
	IX-18-42	....	....	....	..
<i>B. tyrannus</i>	IX-4-42	30.2	XI-26-42	25.1	5.1
	IX-18-42	....	....	....	..
<i>S. maculatus</i>	IX-4-42	30.2	VIII-21-42	26.1	4.1
	IX-18-42	....	....	....	..
<i>M. tomcod</i>	V-14-43	29.1	V-28-43	22.5	6.6
<i>C. regalis</i>	IX-4-42	30.2	VIII-21-42	26.1	4.1
<i>S. aquosus</i>	IV-30-43	29.1	V-28-43	22.5	6.6
<i>M. saxatilis</i>	IX-4-42	30.2	VIII-21-42	26.1	4.1
<i>C. harengus</i>	IV-30-43	29.1	V-28-43	22.5	6.6
	V-14-43	....	....	....	..
<i>M. aeneus</i>	IX-18-42	30.2	V-28-43	22.5	7.7
<i>P. saltatrix</i>	X-2-42	28.8	X-2-42	28.8	0.0
	X-16-42	....	X-16-42	....	..
<i>P. evolans evolans</i>	IX-4-42	30.2	VIII-21-42	26.1	4.1
	IX-18-42	....	....	....	..
<i>A. mitchilli</i>	IX-4-42	30.2	VIII-21-42	26.1	4.1
<i>B. chrysura</i>	IX-18-42	30.2	VIII-21-42	26.1	4.1
<i>T. onitis</i>	IX-4-42	30.2	VIII-21-42	26.1	4.1
	IX-18-42	....	....	....	..
<i>S. foetens</i>	IX-4-42	30.2	VIII-7-42	28.6	1.6
	IX-18-42	....	....	....	..

The condition of the water, recorded as turbidity, apparently had more effect upon the numbers of fishes present on the sandy bottom than the condition of the sky. Unfortunately less data is available concerning this factor than for those previously discussed; it is also true that the conditions which gave rise to the turbidity may have been the primary agents affecting the fish. However, on six different occasions when small collections were taken the water was recorded as turbid (Table I). Moreover since it is likely that turbidity reduces visibility of the fish so that it would be less apt to see the collector and net, it is reasonable to assume that there would be a better chance of

sampling the population. But since the degree of turbidity was not noted with complete regularity, it cannot be assumed with certainty that abundance was conditioned by this factor. It also seems probable that there was some relationship between turbidity and the number of species. For example, the number of species, as well as individuals, was low on June 11 and June 25, 1943, turbid water being recorded on both these days. The data further suggests that the demersal species were less affected by turbidity than were the pelagic forms, for on days when water conditions were recorded as "very turbid," *Pseudopleuronectes americanus* and *Syngnathus fuscus* were comparatively abundant. Indeed, it seems wholly logical that demersal species would feel the effects of suspended material to a lesser degree than forms that habitually remain at higher levels.

ANALYSIS OF THE FISH POPULATION AS A WHOLE

Major Categories

Above and beyond a consideration by species, the fish collected from Morris Cove at biweekly intervals from July 10, 1942 through June 25, 1943 can be subjected to analysis on other grounds. Two additional classifications, each of which have various subdivisions, suggest themselves in this connection. First, on the basis of geographical distribution, four categories can be distinguished. Second, on the basis of size, and concurrently age, three divisions are readily apparent.

Geographical Distribution

Turning first to the division of the fish population on the basis of the geographical distribution of the various species involved, Greeley (1939) recognized three groups in his work along the Long Island shoreline. He designated these as permanent residents, immature summer residents, and breeding migrants. While this classification may be adequate for an area such as the whole shoreline of Long Island Sound, it is possible to make various refinements for a particular region such as Morris Cove and probably for any other definite shore biotope. Four divisions are recognized in the present study: 1) resident at all stages of the life history, 2) resident only during the immature stages, 3) immature offspring of breeding migrants, and 4) immature migrants. The term "resident" as used in the first division obviously refers not only to the sandy-bottom shore zone under consideration but also to

the broad geographical area of Long Island Sound or southern New England. As used in the second division, it refers only to the particular biotope here studied, although the adults live sufficiently near at hand so that the species may be said to be residents of the general region. These first two categories, then, include fish which spend the great majority or a part of their life history in a shore zone of the Morris Cove type, and which do not undertake extensive coastwise migrations with the seasons, although some of them may move on and off shore at different times of year. The last two categories include forms which are not permanent residents of this general region, since they only appear in the area seasonally either through the migration of adults which breed nearby and produce young which occupy the biotope, or the migration of immature fish which are the product of a more distant spawning. It should be noted that in these divisions there is no place for mature migrants from regions considerably to the south or north. A fifth category of this sort could be added, but its members are so limited and rare in this biotope that they do not warrant such treatment.

Arbitrary classification in the four categories listed above is extremely difficult for many of the species in the Morris Cove collections. Therefore it is necessary to qualify a number of the forms which are included under the different headings. This is so because of the lack of definite knowledge of spawning and migratory habits, together with variations in behavior from season to season in certain species. Such qualifications regarding given species are discussed below, and it should be understood that these forms have been placed in the different categories on the basis of existing information which in many cases is so inadequate as to make their classification little better than surmise.

1.) *Resident at all stages of the life history.* These are species which are found in the sandy-bottom shore-zone biotope for the greatest part of the life cycle, and which were so represented in the Morris Cove collections. They are normal inhabitants of this area, both in young and old stages, except during the extremely cold parts of the winter, when the shallow part of the shore zone is apparently completely devoid of fishes. These include:

Menidia menidia notata
Syngnathus fuscus

Fundulus majalis
Fundulus heteroclitus

Certain qualifications are clearly necessary for the species in this classification. *M. menidia notata* was collected in all its stages from the sandy-beach shore zone, with the exception of spawning individuals; even these latter were not necessarily precluded, since definitely ripe fish were taken in the area. But Hildebrand (1922) and Fowler (1918) indicate that a weedy situation is preferred. Therefore this species may be considered as a shore-zone resident, which regularly occupies this biotope, although it is not confined to the sandy beach habitat. *S. fuscus* is also a permanent resident; but in late July most of the adults which were present in the spring and early summer left, and the collections were composed of immature individuals. The two species of *Fundulus* were taken both as adults and juveniles; these fish are rather catholic in their habitat preference, but they are definitely shore-zone residents although not necessarily confined to the sandy beach.

2) *Resident only during the immature stages.* These are species which are generally considered to be year-around residents of the region, but which are present in the biotope of the type under consideration only as juveniles. The species so classified are:

<i>Pseudopleuronectes americanus</i>	<i>Tautoga onitis</i>
<i>Scophthalmus aquosus</i>	<i>Prionotus evolans</i>
<i>Microgadus tomcod</i>	<i>Spheroides maculatus</i>
<i>Myoxocephalus aeneus</i>	<i>Anchoa mitchilli</i>

With the exception of the last three species, the inclusion of the various fish in this list needs but little qualification. It is true, however, that almost all of these forms probably come into the area as mature individuals on rare occasions, and that with equipment better suited to the capture of larger fish than the gear which was used (30-foot minnow seine), they would have been taken from time to time. Evidence from trawl hauls in connection with tagging experiments indicates that at least the adults of the two flounders concerned often come close to the area which was worked in sufficient numbers so that it would be almost inconceivable that a few of them should not stray even closer toward shore. And several apparently mature *M. tomcod* were taken in the course of this study during the fall of 1942. Furthermore, adult *M. aeneus* were seined at Morris Cove and adjoin-

ing areas in 1942 and 1943. But in all such instances the mature individuals were so rare and so heavily outnumbered that these species fit more logically in the second than in the first category. It will be noted also that all the forms listed as being resident only during the immature stages grow to much larger sizes as adults than the members of the first category—*i. e.*, those that are resident at all stages of the life history. Since size is apparently a limiting factor in the Morris Cove biotope (pp. 75-76), and since the above-mentioned adults only come into the area as occasional strays or possibly pass through part of it without becoming in any sense of the word resident, it seems reasonable to list these species as members of the sandy-bottom shore zone only during the immature stages. The adults are clearly not members of the population under consideration.

More serious qualification of the last three species in this list, and possibly *M. tomcod*, is necessary. Because of insufficient knowledge of the fish concerned, it is difficult to state with any degree of certainty whether or not these forms are year-round residents of southern New England. Subsequent investigation may show that they are migrants from more distant areas which breed in this region, thus producing young which then come to occupy biotopes of the Morris Cove sort during the early stages of their life histories. Nichols and Breder (1926) state that *M. tomcod* move off shore in the summer; the present authors wonder if there is not a migration northward in the late winter or spring, with a corresponding return to southern New England waters in the fall. Certainly this species is rarely seen in the Connecticut trawl fishery in the summer; if it undertook nothing more than seasonal off- and on-shore movements, it might reasonably be expected to be a regular, if small, component of the catch of these boats from May to October. Also it is suggested by various authors (*e. g.*, Nichols and Breder, *loc. cit.*; Bigelow and Welsh, 1925), that *P. evolans* and *S. maculatus* apparently go into deeper water during the winter. Again it seems quite possible from the highly seasonal appearance of these species and from their total absence in the winter trawl catch from deeper water, that they undertake marked coastwise migrations—north in the spring and south in the fall. It may also be that a few individuals of the three above-mentioned species remain in these waters in all seasons, as is true with the striped bass (Merriman, 1941), thus leading to the false supposition that these are not coastwise migratory forms. Finally *A. mitchilli* may not be a year-round

resident of this region, but may spend its winters farther to the south; that it is a migratory form is suggested by the comments of Bigelow and Welsh (1925) who state that "it appears from May to October in Southern New England waters." But as with the other species considered above, it seems best to include this fish in this category until fuller knowledge of its life history and habits provides information to the contrary.

3) *Immature offspring of breeding migrants.* These are the immature individuals of species that migrate to the region and spawn. They include:

Brevoortia tyrannus

Menticirrhus saxatilis

Cynoscion regalis

Clupea harengus

Pomatomus saltatrix

Here again, the assumption that all of these forms behave in identical patterns is misleading and some qualification is necessary. Adult *C. harengus*, although "present at all seasons in irregular numbers," is "abundant to the eastward in fall" (Nichols and Breder, 1926), the time of spawning in this region. It would seem, therefore, that mature herring in all probability migrate south at this time of year to spawn in southern New England waters—at least close enough to New Haven so that the young are distributed throughout the region. On the other hand, the remaining species in this category migrate *from* the south, and spawn in southern New England waters as well as elsewhere. Many, if not all of the fish here listed, have prolonged spawning seasons; reproduction also occurs over a wide coastal range. Unquestionably some, and perhaps the majority of the young encountered in an area such as the Morris Cove biotope are the product of reasonably local spawning. It is equally certain that some of the immature individuals are the result of more distant spawnings with a subsequent migration of the young. It is the mixture of individuals from nearby and further removed spawnings over rather long periods of time that makes analysis by length-frequency curves alone extremely hazardous as indicated in the preceding sections of this paper. The spatial and temporal nature of the spawning of these species, as well as the apparent intermixture of the young produced at different periods and in different areas, is a consistent source of difficulty.

4) *Immature migrants*. These are the young individuals which are produced elsewhere and then migrate to southern New England waters. In general the adults of these species are not found in the region, or if they do occur, they are so rare as to warrant consideration only as stragglers or strays, while the young are sufficiently abundant to be included as true members of the population. Greeley (1939), in his survey of Long Island, indicated that the pompano (*Trachinotus* spp.) fell into this general category. In the Morris Cove collections only two of the more abundant species fit here:

Bairdiella chrysura

Synodus foetens

Adult *B. chrysura* occur north of New York in extremely limited numbers, although Welsh and Breder (1923) state that it is common in New Jersey in the summer and early fall, spawning occurring from June to August. Perlmutter (1939) found the adults uncommon on the south shore of Long Island, although the young were relatively abundant throughout the summer in this area and even further north. He suggested that this species may spawn in New York waters, since eggs and larvae were taken in the vicinity of Moriches Inlet. That considerable numbers of young apparently migrate to the north and east is clearly indicated by Perlmutter's (*loc. cit.*) observations which are substantiated fully by the present study. These authors have not encountered spawning silver perch in Connecticut waters. In the same way, immature *S. foetens* were taken with some regularity in the Morris Cove collections, but these authors have seen only one mature lizard fish in this region, and that was taken in November in outer Long Island Sound. Therefore it seems logical to believe that immature individuals migrate from spawning areas further to the south.

Finally, in regard to the division of the fish population on the basis of geographical distribution, the less abundant species (Table XXII) cannot be classified in separate categories because their numbers are so small. Although none of them can be considered residents of the Morris Cove biotope, most of them are probably residents of southern New England. Clear exceptions are *Caranx hippos* and *Leiostomus xanthurus*, both of which are immature migrants from the south. *Prionotus carolinus* may fall into this group also, and the young of *Pollachius virens* apparently migrate from the east and north. Of

all these less abundant species, *Anguilla rostrata* is probably the one which comes closest to qualifying as a resident of the area under consideration, in that it is found just outside the zone reached by the seine and strays into shallower water with some degree of regularity.

Size

Turning to the division of the fish population on the basis of size, the following categories, listed in order of abundance, seem to describe the components of the Morris Cove collections best.

1) *Fish-of-the-year*. All of the more abundant species were apparently represented by fish-of-the-year, with the possible exception of *Syngnathus fuscus*, where the age of the smaller individuals is in doubt (pp. 27-28).

2) *Mature adults*. A number of species were represented by mature adults, the most obvious being *Menidia menidia notata*, *Syngnathus fuscus*, and *Fundulus heteroclitus*. *S. fuscus* adults, as indicated above, were seasonal in their appearance. A single adult *Fundulus majalis* and several *Microgadus tomcod* were seined, the latter probably being a chance capture of individuals in the spawning movement. The collections also contained specimens of *Scophthalmus aquosus* and *Myoxocephalus aeneus* which were large enough to be mature adults, as judged by comparison with fish of these species taken in other studies in these waters.

3) *Fish of other year-classes*. Because of the lack of adequate data concerning the life history of so many of the species included in this study, this category is somewhat problematical. The modes of the length-frequency curves and the size ranges of many of the species taken in Morris Cove that are residents of the region indicate that fishes of intermediate ages were present on occasions—e. g., *Menidia menidia notata*, *Syngnathus fuscus*, *Fundulus* spp., *Myoxocephalus aeneus*, and *Tautoga onitis*. But in the absence of more detailed knowledge none of these species can be included with any degree of certainty, especially since their respective ages at maturity are unknown. However, it does seem reasonable to assume on the basis of the available information and the general observations of these authors that intermediate stages of *Pseudopleuronectes americanus*

and *Scophthalmus aquosus* were present in the collections on various occasions. That the edge of a larger-sized population of both species of flounders was reached by the seine possibly explains the presence of these fish. There is little to indicate that either species spawns in any quantity at a length of 200 mm. or less.

Size Stratification

In connection with the classification of the fish population on the basis of size it is significant that a definite relationship existed between the size of the fishes and the nature of the area studied. The fishes encountered were limited as to length, and in general this seemed to be true regardless of age. Reference to the length-frequency distributions of the various species shows that the range in sizes averaged well below the 100 mm. mark. This was true for fish that were resident and adult, as well as for fish-of-the-year. Most of the shore-zone residents of the area here studied are fish that do not grow to lengths much greater than 100 mm., except for the oldest individuals which are generally few in number. The largest *Menidia menidia notata* collected measured 129 mm. in standard length, but more significant is the fact that the greatest mean length computed for any of the larger collections of this species was 82.2 mm., the lengths for that particular sample ranging from 62 to 100 mm. In general the two species of *Fundulus* were less than 100 mm. in length. For example, on September 4 the *Fundulus heteroclitus* collection consisted of two fairly well marked modes, the larger apparently composed of adults with a mean length of 72.9 mm. On the other hand, *Syngnathus fuscus* formed an exception to the general rule as regards size stratification. In May and June only adults were present, and these were much longer than representatives of other species collected from the area (Fig. 6). In July and August the population of *Syngnathus fuscus* was represented by two size-classes which were recognizable as adults and juveniles, the adults being slightly larger than those taken during the earlier months. Thereafter the area was occupied by juveniles exclusively, and the mean length of these animals ranged near the 100 mm. length mark. In regard to the resident immature species, *Pseudopleuronectes americanus* and *Scophthalmus aquosus* were interesting in that there is definite indication that some of the fish in the older age groups, juveniles in or approaching the second year, continue to inhabit the shore zone investigated in this study (or

rather, return to it after the winter) if they are less than approximately 100 mm. All of the immature offspring of breeding migrants and the few immature migrants were within the range of size necessary to fit this generalization.

Thus it would seem that the shore-zone fishes are definitely limited as to the size at which they occupy the Morris Cove biotope. Under most circumstances the different species are not found in the area after they reach 100 mm., although there are occasional strays and other exceptions to the general rule. The most notable and regular exception is *Syngnathus fuscus*, but it should be mentioned that if size were judged by volume rather than length this fish would fall far below other species of the area which are less than 100 mm. long. This size stratification holds regardless of age, as illustrated in the case of the flounders. Furthermore, this shore zone area acts as a "nursery ground" for fish-of-the-year of many species and for older individuals of some of the species—an area in which the young may and frequently do stay until they approach the 100 mm. mark. Such "nursery grounds" are unquestionably of considerable significance in the maintenance of stocks that are of commercial significance.

Abundance

Before discussing the abundance of fishes occurring in the Morris Cove biotope, it seems logical to evaluate the area under consideration and to show that it is a definite ecological entity, for otherwise the relative number of fishes contained in it has little or no significance.

The sandy-bottom shore zone is a marginal area, lying between the open sea and the land, which is difficult to define because of the changes to which it is subjected as the tides ebb and flow, and because its outer edge is not sharply delimited from the deeper water region. That the deeper-water zone is fundamentally distinct was apparent from observations on the composition of the catch in a small-meshed trawl operated not far off the Morris Cove sandy-beach biotope in 1943. This zone contained some small individuals and larger fish of a number of the types encountered in-shore, as well as additional species. Subsequent investigation may show that the fish from the shallow- and deeper-water zones intergrade to varying extents under different conditions. Since large fish were occasionally taken in the Morris Cove collections, *e. g.*, flounders, it would appear that the edge of what seems to be an overlap region between the two zones was ap-

proached in the present work. Furthermore, the fact that the vast majority of the individuals encountered in the present study were small, many of them fish-of-the-year, lends emphasis to the conception that this is an area that must be considered as a separate and distinct entity with its own highly characteristic fauna. The composition of the catch also points to the idea that here may be found factors which are important in promoting the growth of the contained fishes in their early stages.

No definite evaluation of the factors associated with the nature of the substrate can be made since it is essentially the same both seaward and shore-ward. It seems extremely doubtful also if the chemistry of the area is sufficiently different from the conditions found somewhat further from shore to provide any clear-cut limitations, although it is reasonable to suppose that the variation in salinity is greater due to the direct influence of drainage from the shore, and that the oxygen content is perhaps higher at times than in the deeper-water zone. On the other hand, physical conditions, especially depth and temperature, may establish recognizable limits to the area—limits which may work to the advantage of the contained fish population in some instances and to its disadvantage in others. Thus depth is probably a factor which limits the volume of the organism relative to the volume of the surrounding medium, both in terms of the size of the individuals concerned and the total mass of the entire population. At the same time the shallow water of the area may offer refuge from larger predators which more normally occur somewhat further off shore. Temperature may also be a differentiating factor, for its range is unquestionably greater than in deeper waters. The extremely high and low levels in the summer and winter may be disadvantageous, as may be the more rapid fluctuations which would characterize an area so near the inter-tidal zone. On the other hand definite advantages may accrue from the periodic flooding and exposure at the extremes of the tides and concurrent effects—*e. g.*, the rapid warming in the spring months to provide adequate conditions for the spawners and young which are able to make use of the area. Finally, the biological conditions may offer means of delimiting the area, for the bottom fauna of the shallow-water zone may possibly differ from that further off shore in quite as definite a manner as does the fish population, if not more so.

That this biotope is an ecological entity, then, is clearly indicated

by the nature of the fish population here studied. Unquestionably it can be delimited further, as suggested above, by comparative physical and biological data; and possibly additional refinements could be provided on chemical bases, but the demonstrated fact that a characteristic population of fishes exists in this area provides undeniable evidence that this is a definite ecological facies.

It should be mentioned also that there are two well defined subdivisions within this shore-zone facies. In terms of the fishes encountered, these can be designated as pelagic and the demersal. These subfacies are recognizable in part on the basis of the morphology of the fish concerned. But the size of the fishes taken in the Morris Cove collections indicates that the whole area is a unit, the fish population of which, although divisible into sub-facies, is competitive throughout. There appears to be much evidence that the volume of fish is related to the volume of water, irrespective of the particular mode of life involved. Nevertheless, distinctions in the behavior of pelagic and demersal forms, as during the periods of turbid water, were apparent.

It does not seem out of place to suggest that the shallow-water shore zone is an area where energy values are readily acquired and most efficiently utilized. Incoming tides conceivably bring with them planktonic elements which, because they move in and out again within a limited amount of space, are more concentrated, and thus more available. Efficient utilization is perhaps enhanced in that the limited volume of the surrounding water offers a better opportunity for heat acquisition, both from the sun and the underlying bottom. The fact that the greater part of the fish population is composed of fish-of-the-year that grow rapidly lends credence to the idea. Regarding some of the older fishes which are classed as shore-zone residents and which generally do not exceed the limits of size associated with fish-of-the-year of other species, their energy requirements perhaps differ from those of younger individuals, but this does not exclude them from the area. Instead, the limiting factors seem to be the size of the individuals (pp. 75-76) and the total volume of the fish population in the biotope (pp. 83-85).

When the numbers of individuals of the various species of fish in the 1942-1943 biweekly Morris Cove collections were examined, it was immediately obvious that some kinds were more abundant than others. This suggests that some of the more plentiful forms domin-

ated the subfacies in which they were found, and hence (p. 78), the entire facies—for if a species of fish is consistently present and able to withstand the pressure exerted by invading forms, it may be considered dominant in the sense that it is the organism at the apex of an Eltonian pyramid. This does not mean that there are not other dominants at the various levels of the pyramid. In any ecosystem organized in trophic levels there are apical, intermediate, and basal dominants. The apical dominant includes the species of the highest level controlling the biocoenosis. The basal dominant includes the controlling organisms at the lowest level. Normally the apical dominant will be the largest common predator, the basal dominant the major photosynthetic species. In the Morris Cove ecosystem the fundamental energy-converting organisms are at the base of the Eltonian pyramid, and on this base are the zooplankters, bottom-dwelling invertebrates, and certain nekton; at the peak are the fish, the apical dominant. All the fish in the area would be included in the pinnacle of the pyramid, but superimposed upon the whole structure, and at the same time deeply imbedded in the substance of the pinnacle, would be the most abundant species of fish encountered. The main feature in the consideration of the fishes of the shore zone is the analysis of a constantly shifting population. The composition of the aggregation of fishes is never twice the same and the precise make-up of the peak of the Eltonian pyramid varies correspondingly. Hence there are degrees of apical dominance—that is, not only will the volume of fish at the peak vary, but also the predominant *species* of fish within the peak will vary both in number and kind. Thus one fish may dominate the shore zone for a time and then be supplanted by another. The length of time during which such an organism is present in a dominant position is indicative of its degree of dominance. The problem is to evaluate this factor.

As already indicated in the discussion by species, two classes of fishes are recognized, the more abundant and the less abundant. The more abundant are those that were present in sufficient quantities to be placed in the ranks of the first ten species, these ranks being based on the relative numbers of individuals (p. 80). The less abundant species (Table XXII) were stragglers from other environments, and were so few in number that they do not merit consideration in this connection.

Two approaches have been used to evaluate the abundance of the

more numerous species in the Morris Cove collections. These can be termed "relative abundance" and "total abundance."

Relative Abundance. This involves an approach which indicates the relative position of the various species on any given date, and which, when summarized, gives a true expression of positional values regardless of the influence of extraordinary numbers of individuals present on any one day. For estimating relative abundance a system of scoring was devised which facilitated the summarization of the positional rank for each species at different times during its presence in the area. All species in the first ten ranks were assigned a score, the first rank being given 10, the second 9, the third 8, and so on until the form in tenth place was assigned a score of 1. The advantages resulting from this system are merely simplicity and direct comparison in that the score allows an animal high in the ranks of abundance a high score. No attention need be given significant figures relating to the numbers of individuals of a particular species. The values derived refer to position only. The disadvantages are that the system is arbitrary and has no real value in terms of the collection except for position. However, when position in rank is assigned to a

TABLE XXV. RELATIVE AND TOTAL ABUNDANCE SUMMARY

Species	Relative Abundance		Total Abundance		Number
	Rank	Score	Rank	%	
<i>Menidia menidia notata</i>	1	134	1	50.21	8297
<i>Pseudopleuronectes americanus</i>	2	132	5	5.15	851
<i>Syngnathus fuscus</i>	3	109	3	9.40	1554
<i>Fundulus</i> spp.	4	85	6	3.70	611
<i>Brevoortia tyrannus</i>	5	51	2	17.86	2952
<i>Spheroides maculatus</i>	6	42	7	2.43	401
<i>Microgadus tomcod</i>	7	39	8	1.95	323
<i>Cynoscion regalis</i>	8	26	9	1.75	289
<i>Scophthalmus aquosus</i>	9	24	12	0.33	54
<i>Menticirrhus saxatilis</i>	10	24	11	0.41	68
<i>Clupea harengus</i>	11	20	4	5.42	895
<i>Myoxocephalus aeneus</i>	12	15	14	0.21	34
<i>Pomatomus saltatrix</i>	13	9	16	0.09	15
<i>Prionotus evolans evolans</i>	14	9	10	0.56	92
<i>Anchoa mitchilli</i>	15	6	13	0.27	45
<i>Bairdiella chrysura</i>	16	6	15	0.13	22
<i>Tautoga onitis</i>	17	6	17	0.08	14
<i>Synodus foetens</i>	18	3	18	0.05	8

species, a figure denoting the rank has to be used in any case, and by eliminating the intermediate percentage calculation, proportionate numbers of individuals need be considered only on the basis of the rank which a particular species occupies on the day of the collection. In this way true values can be assigned to species that were consistently present, such as *Pseudopleuronectes americanus*, as opposed to species present in large numbers but sporadic in their occupancy of the area, such as *Brevoortia tyrannus* (Table XXV).

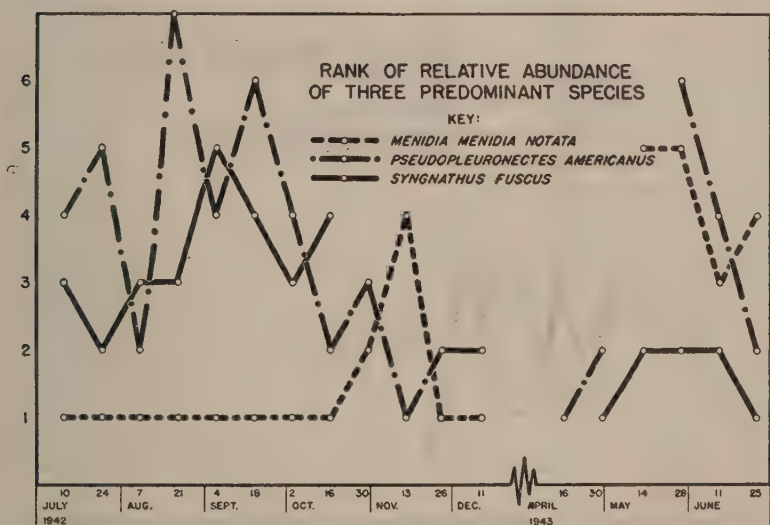


Figure 18. The ranks of abundance occupied by the three most common species, *Menidia menidia notata*, *Pseudopleuronectes americanus* and *Syngnathus fuscus*.

The ranks of relative abundance of the more common species are illustrated in Figs. 18 and 19. The higher ranks of abundance were largely dominated by the same species throughout the year. Three of the genera were shore-zone residents, *Menidia menidia notata*, *Syngnathus fuscus*, and the two species of *Fundulus*. Two species were resident immature fish, namely *Pseudopleuronectes americanus* and *Spheroides maculatus*, and one, *Brevoortia tyrannus* was the immature offspring of a breeding migrant. In the summer and fall the dominant species was *M. menidia notata*. From July 10 to October 16, 1942, this species occupied the first rank of relative abundance.

It was supplanted by *B. tyrannus* on October 30, and by *P. americanus* on November 13, but it regained the first rank on November 26, and December 11. In the spring *M. menidia notata* did not enter prominently into the ranks of abundance. On March 19, 1943 the only fish taken was a single *Fundulus majalis*. On April 16 *P. americanus* was the first species, on April 30 *S. fuscus* occupied first rank, and in May the first position was held by *Clupea harengus*. In early June

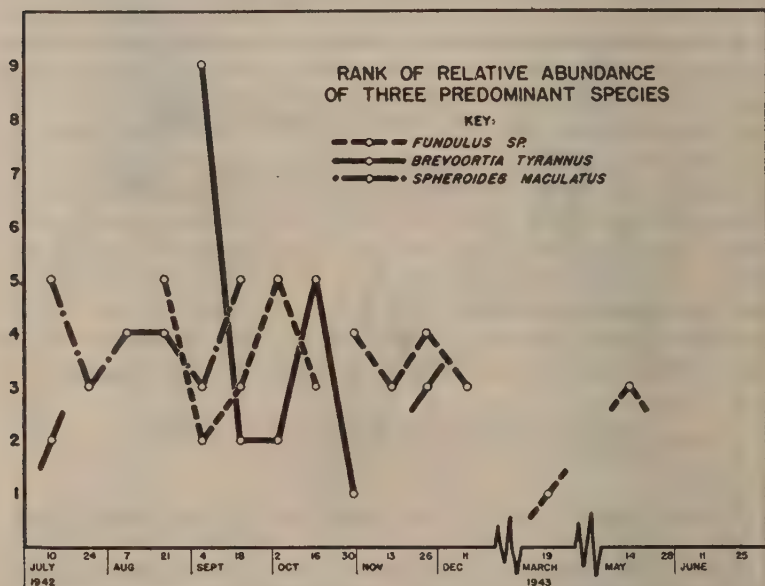


Figure 19. The ranks of abundance occupied by the three species in the fourth, fifth, and sixth ranks in the summary of the relative abundance indicated in Table XXV.

Microgadus tomcod was first, and in late June this rank was occupied by *S. fuscus* for the second time that spring. The second rank of abundance was divided between a variety of species. *B. tyrannus* was second on July 10, September 18, and October 2, *S. fuscus* on July 24, May 14, May 28 and June 11, *P. americanus* on August 7, October 16, November 26, December 11, April 30, and June 25, *Cynoscion regalis* on August 21, *F. heteroclitus* and *F. majalis*, considered together, on September 4, *Myoxocephalus aeneus* on November 13, and *Scophthalmus aquosus* on April 16. The third rank of abun-

dance was divided between the above-listed species, with the addition *Spheroides maculatus* and *Pollachius virens*, the latter being placed in this rank rather than second on April 16 when it was tied with *Scophthalmus aquosus*, since it appeared in the first ten places of abundance only once. The same list of species occupied the fourth rank of abundance. To the fifth *Anchoa mitchilli* was added, to the sixth *Menticirrhus saxatilis*, *Pomatomus saltatrix* and *Osmerus mordax*, to the seventh *Prionotus evolans* and *Bairdiella chrysura*, and in the eighth *Tautoga onitis* appeared.

Obviously the above considerations have to do with the entire facies, and the subfacies are disregarded. Paucity of information at the different stages of the life history of many of the species encountered in Morris Cove precludes the classification of the entire list of the more abundant species on the basis of ranks of abundance of free-swimming and bottom-living forms. However, the dominant species for the entire area, *M. menidia notata*, is free-swimming. Second and third positions of relative abundance were occupied by the demersal *P. americanus* and *S. fuscus*. The fourth and fifth places were filled by the genus *Fundulus* and *B. tyrannus*, the former being predominantly free-swimming, the latter clearly so. The sixth and seventh places fell to *S. maculatus* and *M. tomcod*, both of which are essentially demersal. It is at least clear from the above that there is no overwhelming predominance of the fishes of one mode of life over the other—the one does not exist to the exclusion of the other.

Total Abundance. Here the approach indicates the fluctuations in total numbers collected on one day as compared with the total numbers taken on any other dates; when summarized, the total abundance of a single species in terms of the percentage of the whole of the collections in the entire study is shown (Table XXV).

Interesting trends are revealed in the analysis of the total abundance of the species by dates of collection (Fig. 20). Three peaks were reached during the summer and fall of 1942—July 10, September 18, and October 30. These were followed by marked regression in numbers of individuals, and then slow, gradual recovery, except in November when the numbers declined as winter approached. This suggests a possible effect of population pressure on the number of individuals—*i. e.*, in an area inhabited by highly mobile and gregarious species of fish under optimal living conditions the tendency is to build up the

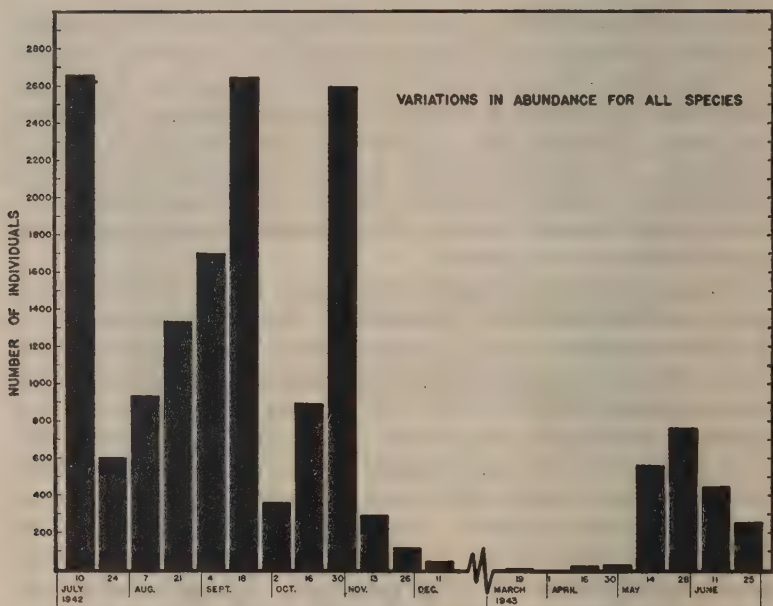


Figure 20. Variations in total abundance on the days collections were made.

population gradually to a point where the density reaches a definite level or supersaturation point, following which the fish disperse and then repeat the building-up process. That the recurrent peaks and subsequent drop in numbers followed by a regular increase as indicated in Fig. 20 is a true reflection of actual conditions, cannot be stated with absolute certainty. More frequent samplings might have altered the picture. Furthermore, it should be noted that the two predominant species in each of three peaks of maximal abundance (Fig. 21) are types which school heavily, and it could be argued therefore, that they were both present in great numbers throughout the summer and fall, but that the seine only happened by chance to pass through the schools on three occasions thus giving a false picture of great numbers. That such is not the case is indicated not only by the method of seining, which covered the area under consideration with such thoroughness as to almost preclude this possibility, but also by the regularity of the cycle of abundance. The similar heights of the three peaks, subsequent decrease, and eventual rebuilding of the

population in regular cyclical fashion provides good evidence that the picture presented here is not false and is not the result of inadequate sampling.

It is interesting to note that the peaks of abundance do not correspond with the peaks of variety (Fig. 21). For example, a wider

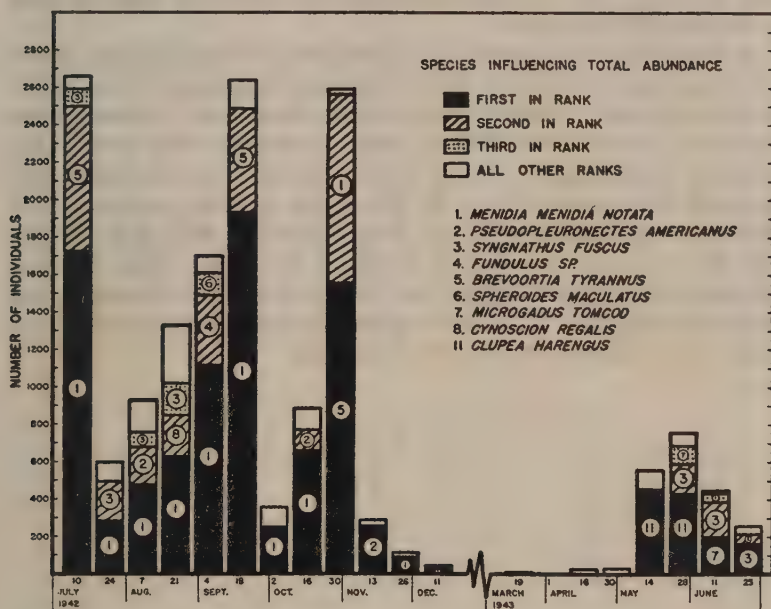


Figure 21. The species influencing the total abundance of the collections.

variety of species was present in Morris Cove on August 21 than at any other time, yet there were only a little more than half as many individuals on that day as compared with the catch one month later. This would indicate that the extremes of abundance are not necessarily dependent upon a wide variety of species; instead the extremes seem to result from the presence of an extraordinary number of individuals of a few species.

Further reference to Fig. 21 shows that during summer and fall the fluctuations in total abundance were largely conditioned by *M. menidia notata*. The next most prominent species in this connection was *B. tyrannus*. In the spring *C. harengus*, *M. tomcod* and *S. fuscus*

were dominant influences. On the basis of total number of individuals encountered during the year, *M. menidia notata* was first in that, of the 16,525 fishes studied, 8,297 were of that species. The next species, *B. tyrannus*, was represented by 2,952 individuals, *S. fuscus* was third with 1,554, *C. harengus* was fourth with 895, *P. americanus* was fifth with 851, and the two species of *Fundulus* considered together were sixth with 611 individuals.

In concluding the discussion on abundance a consideration of the fish occupying the upper six ranks of relative abundance (Table XXV) seems significant. On the basis of *relative* abundance, if these species had been present in the first six ranks consistently they would have attained an aggregate score of 810 by the system outlined above. Actually they scored 554, or 68.3% of the possible maximum. On the basis of total abundance, *i. e.*, the sum of all the fish taken throughout the year, they constituted 92.0% of the total. Thus the first six species made up 92.0% of the volume of all the collections, but they dominated the individual collections, and hence the fish population of the biotope, only 68.3% of the time.

TABLE XXVI. THE FISHES COLLECTED FROM MORRIS COVE ARRANGED IN THE ORDER OF RELATIVE ABUNDANCE FOR EACH DATE

Date	Number of species collected	1st Species	No.	2nd Species	No.	3rd Species	No.	4th Species	No.
VII-10-42	10	<i>M. m. notata</i>	1722	<i>B. tyrannus</i>	744	<i>S. fuscus</i>	93	<i>P. americanus</i>	30
VII-24-42	9	<i>M. m. notata</i>	282	<i>S. fuscus</i>	212	<i>S. maculatus</i>	43	<i>C. regalis</i>	25
VIII-7-42	11	<i>M. m. notata</i>	479	<i>P. americanus</i>	199	<i>S. fuscus</i>	82	<i>S. maculatus</i>	55
VIII-21-42	16	<i>M. m. notata</i>	629	<i>C. regalis</i>	222	<i>S. fuscus</i>	171	<i>S. maculatus</i>	142
IX-4-42	12	<i>M. m. notata</i>	1115	<i>Fundulus</i> Spp.	377	<i>S. maculatus</i>	118	<i>P. americanus</i>	42
IX-18-42	12	<i>M. m. notata</i>	1938	<i>B. tyrannus</i>	550	<i>Fundulus</i> Spp.	64	<i>S. fuscus</i>	42
X-2-42	11	<i>M. m. notata</i>	254	<i>B. tyrannus</i>	30	<i>S. fuscus</i>	22	<i>P. americanus</i>	16
X-16-42	11	<i>M. m. notata</i>	661	<i>P. americanus</i>	107	<i>Fundulus</i> Spp.	37	<i>S. fuscus</i>	31
X-30-42	6	<i>B. tyrannus</i>	1565	<i>M. m. notata</i>	1003	<i>P. americanus</i>	16	<i>Fundulus</i> Spp.	8
XI-13-42	6	<i>P. americanus</i>	264	<i>M. aeneus</i>	9	<i>Fundulus</i> Spp.	6	<i>M. m. notata</i>	3
XI-26-42	4	<i>M. m. notata</i>	88	<i>P. americanus</i>	24	<i>B. tyrannus</i>	5	<i>Fundulus</i> Sp.	1
XII-11-42	3	<i>M. m. notata</i>	37	<i>P. americanus</i>	4	<i>Fundulus</i> Sp.	1	....	..
III-19-43	1	<i>Fundulus</i> Sp.	1	....	...	....	..	....	..
IV-16-43	6	<i>P. americanus</i>	16	<i>S. aequosus</i>	2	<i>P. virens</i>	2	....	..
IV-30-43	6	<i>S. fuscus</i>	12	<i>P. americanus</i>	11	<i>S. aequosus</i>	3	<i>C. harengus</i>	1
V-14-43	10	<i>C. harengus</i>	464	<i>S. fuscus</i>	39	<i>Fundulus</i> Spp.	31	<i>M. tomcod</i>	12
V-28-43	8	<i>C. harengus</i>	431	<i>S. fuscus</i>	161	<i>M. tomcod</i>	91	<i>S. aequosus</i>	45
VI-11-43	6	<i>M. tomcod</i>	198	<i>S. fuscus</i>	199	<i>M. m. notata</i>	49	<i>P. americanus</i>	2
VI-25-43	10	<i>S. fuscus</i>	169	<i>P. americanus</i>	47	<i>M. tomcod</i>	20	<i>M. m. notata</i>	11

TABLE XXVI. THE FISHES COLLECTED FROM MORRIS COVE ARRANGED IN THE ORDER OF RELATIVE ABUNDANCE FOR EACH DATE (cont.)

Date	Number of specimens collected	5th Species	No.	6th Species	No.	7th Species	No.	8th Species	No.	9th Species	No.
VII-10-42	10	<i>S. maculatus</i>	19	<i>M. saxatilis</i>	14	....	..	....	..	....	..
VII-24-42	9	<i>P. americanus</i>	20	<i>M. saxatilis</i>	13	....	..	....	..	....	..
VIII-7-42	11	<i>A. mitchilli</i>	39	<i>C. regalis</i>	31	<i>P. evolans</i>	28	<i>M. saxatilis</i>	10	....	..
VIII-21-42	16	<i>Fundulus</i> Spp.	67	<i>P. evolans</i>	59	<i>P. americanus</i>	31	<i>M. saxatilis</i>	17	<i>B. chrysura</i>	11
IX-4-42	12	<i>S. fuscus</i>	14	<i>C. regalis</i>	8	<i>M. saxatilis</i>	7	<i>S. foetens</i>	6	<i>B. tyrannus</i>	5
IX-18-42	12	<i>S. maculatus</i>	22	<i>P. americanus</i>	10	<i>B. chrysura</i>	8	<i>T. onitis</i>	5	....	..
X-2-42	11	<i>Fundulus</i> Spp.	14	<i>P. saltatrix</i>	9	<i>M. saxatilis</i>	7	<i>T. onitis</i>	4	....	..
X-16-42	11	<i>B. tyrannus</i>	22	<i>M. aeneus</i>	15	<i>P. saltatrix</i>	6	....	..	....	..
X-30-42	6	....	..	....	..	....	..	....	..	....	..
XI-13-42	6	<i>M. tomcod</i>	2	....	..	....	..	....	..	....	..
XI-26-42	4	....	..	....	..	....	..	....	..	....	..
XII-11-42	3	....	..	....	..	....	..	....	..	....	..
III-19-43	1	....	..	....	..	....	..	....	..	....	..
IV-16-43	6	....	..	....	..	....	..	....	..	....	..
IV-30-43	6	....	..	....	..	....	..	....	..	....	..
V-14-43	10	<i>M. m. notata</i>	9	<i>O. mordax</i>	4		..		..		..
V-28-43	8	<i>M. m. notata</i>	20	<i>P. americanus</i>	11		..		..		..
VI-11-43	6		..		..		..		..		..
VI-25-43	10		..		..		..		..		..

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STUDIES ON THE MARINE RESOURCES OF
SOUTHERN NEW ENGLAND

III. THE POSSIBILITY OF THE UTILIZATION OF
THE STARFISH (*ASTERIAS FORBESI* DESOR)

VOLUME IX, ARTICLE 3

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OF
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III. THE POSSIBILITY OF THE UTILIZATION OF THE STARFISH (*ASTERIAS FORBESI* DESOR)

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ABSTRACT

This work of composite authorship is a cooperative study. It was undertaken as part of a program at the Bingham Oceanographic Laboratory on the practical aspects of the utilization of marine resources in the belief that it is a vital part of our national economy to manage these resources so as to insure their most efficient utilization and maximum productivity.

Biochemical analyses reported herein gave clear indication that the starfish might be of value in poultry and stockfeeds. The aid of various technological laboratories and experiment stations—federal, state and private—was therefore solicited, and the papers from six separate cooperating agencies are included. These experiments provide evidence that starfish meal may be used satisfactorily as one of the protein concentrates in chick rations. Four additional papers by workers in intimate contact with the oyster industry are also presented. These include accounts of the abundance, control and possible uses of the starfish, and give some indications of the problems involved. A final paper discusses the whole matter of the utilization of starfish, summarizes the pertinent evidence, and indicates the need for additional work in this and related fields; it is concluded that the large-scale utilization of starfish as protein feed or fertilizer seems to be entirely impracticable under present conditions.—D. M.

BIOCHEMICAL OBSERVATIONS ON *ASTERIAS FORBESI*

BY G. E. HUTCHINSON, JANE K. SETLOW AND JOHN L. BROOKS
Osborn Zoological Laboratory, Yale University, New Haven, Conn.

The starfish is one of the commonest marine invertebrates in the coastal waters of the northeastern United States and is particularly well-known as a serious pest of oyster-beds. Our attention has therefore been directed toward this animal, not only on account of its abundance, but because it is already captured in considerable quantities by those engaged in oyster culture. Galtsoff and Loosanoff (1939) indicate that *Asterias forbesi*, ground into meal, has been produced and sold in Virginia as an ingredient of food for farm animals and that it has also been used as fertilizer in the same state. Other species appear to have been employed in similar ways in Europe during the first World War; they were also utilized, mixed with oyster-shells, as fertilizer for acid soils, in France during the last century (Heiden, 1887).

Determinations of certain biologically important elements have been made on *Asterias forbesi*, collected in Long Island Sound in February, 1943.

	In starfish dried at 57° C.	In living starfish
Nitrogen	5.32-5.65 %	1.76-1.87 %
Calcium	16.9 %	5.58 %
Sulphur	0.87 %	0.29 %
Phosphorus	0.438 %	0.145 %
Iron	0.017 %	0.0056 %
Manganese	0.0023 %	0.00076 %
Fluorine*	0.016 %	0.0053 %
Boron**	0.0034 %	0.0011 %

These data are in accord with those previously published for calcium and nitrogen. Accepting the usual convention as to the composi-

* Analysis kindly performed by Miss Anne C. Wollack.

** Analysis kindly performed by Dr. Gordon H. Ellis, U. S. Dept. of Agriculture Laboratory, Ithaca, N. Y.

tion of protein, and assuming the calcium present as CaCO_3 , we may conclude that the dry material analyzed consists of about 34 per cent protein and 42 per cent calcium carbonate. The quantity of fluorine should not be great enough to cause inconvenience in practical utilization. The iron content is much lower than that previously reported for this and other species; some seasonal variation may be expected. The chief objection to the use of starfish meal in vertebrate nutrition arises from the high $\text{CaO} : \text{P}_2\text{O}_5$ ratio. In view of the large amount of calcium, the high strontium content of sea-water, and the possibility of injurious effects from the ingestion of excess strontium, it seemed worthwhile to examine starfish meal for the latter element. Unfortunately no good gravimetric method is available and the spectrographic equipment at our disposal does not permit more than semiquantitative estimation. The accompanying plate, however, in which a spectrogram of *Asterias* ash is compared with that of the ash of a pelagic *Sargassum* from the subtropical Atlantic, indicates clearly how much greater is the $\text{Sr} : \text{Ca}$ ratio in the latter than in the former. It appears from the work of Webb (1937) that certain brown algae regularly take strontium from sea water in proportion to calcium in excess of the ratio in the medium. Our observations tend to confirm this conclusion, a fact which may be of practical importance in the utilization of seaweeds for stock feed. It is reasonably certain that in using starfish no danger from excess of strontium need be considered. When liberally applied as a fertilizer, the boron content of starfish meal might make a significant contribution to very boron-deficient soils.

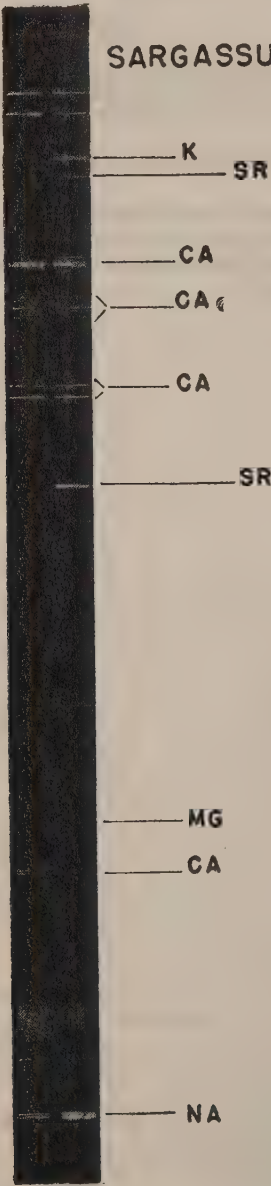
Certain members of the vitamin B complex have been determined microbiologically, under the direction of Dr. Paul R. Burkholder.

Thiamin	1 mgr. per kilo.
Riboflavin	5.5 mgr. per kilo.
Niacin	38 mgr. per kilo.
Pantothenic acid	12 mgr. per kilo.

The low thiamin content of the dried starfish is almost certainly due to post-mortem loss. An analysis by Distillation Products Inc. showed no indication of Vitamin A. Starfish meal incorporated in a Vitamin D deficient diet greatly improved the growth of white rats, but owing to the difficulty of inducing a constant intake, quantitative conclusions can hardly be drawn from the data.

ASTERIAS

SARGASSUM



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DEHYDRATED PEA VINES AND STARFISH MEAL IN POULTRY FEEDS¹

BY H. R. BIRD

Maryland Agricultural Experiment Station, College Park, Md.

The two entirely unrelated products mentioned in the title were investigated as possible substitutes for alfalfa meal and fish meal, respectively. The dehydrated pea vines were furnished by Charles G. Summers, Jr., Inc., New Freedom, Pennsylvania, and contained 102 p. p. m. of carotene and 23.26 per cent crude fiber as compared with 138 p. p. m. of carotene and 20.36 per cent fiber in the alfalfa meal used in this experiment.² The starfish meal was furnished by the Bingham Oceanographic Laboratory of Yale University through the courtesy of Dr. Daniel Merriman.³ This material has been described in an Interim Report of the Bingham Laboratory (April, 1943). Typical analyses show 34 per cent protein, 16.9 per cent calcium and 0.43 per cent phosphorus. In this experiment the starfish meal was compared with a commercial fish meal (chiefly menhaden) as to its ability to supplement a mash (16) containing no animal protein.

Mash 16 has the following composition: ground yellow corn 29.25, ground heavy oats 10, wheat bran 10, wheat flour middlings 10, soybean oil meal (expeller) 30, alfalfa meal 5, oyster shell flour 1.75, defluorinated superphosphate 1, butyl fermentation residue (80 micrograms riboflavin per gram) 1.5, vitamin A and D oil (85 A. O. A. C. Units of vitamin D per gram) 1, salt 0.5, and manganous sulphate tetrahydrate 0.012. This mash contains approximately 20.5 per cent protein, 1.1 per cent calcium and 0.6 per cent phosphorus.

The plan of the experiment is indicated in Table I, which also gives the results. When additions were made of alfalfa meal or pea vine in

¹ Scientific paper No. A68, Contribution No. 1910 of the Maryland Agricultural Experiment Station (Department of Poultry Husbandry). Also published in *Poultry Science*, XXIII, No. 1, pp. 76-77, 1944.

² The crude fiber determinations were made by the Maryland State Inspection Service.

³ The Bingham Laboratory wishes to acknowledge the generous cooperation of Prof. B. F. Dodge, Dept. of Chemical Engineering, Yale University, who permitted the main supply of dried starfish to be ground in his laboratory.

excess of five per cent, or of fish meal or starfish meal, adjustments of the levels of corn, soybean meal, oyster shell, and defluorinated superphosphate were made in an effort to maintain the protein, calcium, and phosphorus levels approximately the same. This could not be done in the case of the mash fed to group 4; it contained approximately 1.4 per cent calcium.

At the beginning of the experiment each group consisted of 30 New Hampshire chicks. Four chicks were lost during the nine weeks of the experiment, two from group 7 and one each from groups 5 and 8.

The results summarized in Table I show clearly that starfish meal

TABLE I. EFFECT OF FEEDING DEHYDRATED PEA VINES AND STARFISH MEAL ON GROWTH, EFFICIENCY, AND SHANK PIGMENTATION OF CHICKS

Group	Modification of Mash 16	Mean live weights of chicks, 9 weeks, in gms.			Efficiency to 9 wks., gms. gain per gm. feed	Shank pigment score; 7 wks
		Male	Female	Mean of Male and Female Means		
1	None	885	807	846	0.336	11.9
2	Plus 4% fish meal	1048	902	975	0.354	10.8
3	Plus 3% starfish meal	1003	895	949	0.350	12.3
4	Plus 6% starfish meal	1012	857	934	0.337	12.2
5	Plus 5% alfalfa meal (10% total)	946	801	874	0.312	14.5
6	Minus alfalfa meal, plus 5% dehyd. pea vine	1009	878	943	0.335	10.6
7	Minus alfalfa meal, plus 10% dehyd. pea vine	1003	880	942	0.318	13.4
8	Minus alfalfa meal, plus 15% dehyd. pea vine	1001	761	881	0.313	14.5

was comparable to the commercial fish meal in its ability to supplement the basal mash. Excellent growth resulted when either of these supplements was fed. The three per cent level of starfish meal was practically as effective as the four per cent level of commercial fish meal, although it supplied only about half as much protein.

Of even greater interest are the results secured when the alfalfa meal was replaced by dehydrated pea vines in the absence of any animal protein. This change resulted in a growth stimulus almost as great as that induced by the four per cent fish meal supplement.

As would be expected, there was a tendency toward greater efficiency of feed utilization when fish meal was fed, and a tendency toward lower efficiency when the higher levels of alfalfa meal and pea vines were fed. Substitution of pea vines for alfalfa meal had no effect on efficiency; hence the superior growth of the groups fed pea vines was

due to greater feed intake. That this was at least partly the result of the greater palatability of the pea vines was indicated by the results of three experiments in which dehydrated pea vines and alfalfa meal were offered to three groups of New Hampshire chicks in separate hoppers for periods of 24 hours. The chicks were five and six weeks old and the groups varied in size. In two trials mash was kept before the birds in additional hoppers but was withheld in the third. The number of grams of alfalfa meal consumed in the three trials was 376, 63, and 192, respectively, and of pea vines 582, 158, and 230, respectively.

The shank pigment scores show that four per cent fish meal had a slight and unimportant adverse effect on pigmentation. The starfish meal did not inhibit pigmentation at the levels fed.

It may be concluded that starfish meal at low levels effectively supplements a chick mash in which soybean oil meal is the only other high-protein feedstuff and that dehydrated pea vines are a good substitute for alfalfa meal and probably have an advantage over alfalfa meal from the standpoint of palatability. Only one sample of each of the products mentioned was used in this experiment. Quality control would be as important for these materials as it is for all feedstuffs, and carotene assays of dehydrated pea vines would be especially important.

STARFISH MEAL IN CHICK RATIONS¹

BY G. F. HEUSER AND J. MCGINNIS

Department of Poultry Husbandry, Cornell University, Ithaca, N. Y.

Starfish meal is produced from the starfish, *Asterias forbesi*, which is one of the commonest marine invertebrates in the coastal waters of the northeastern United States. It is particularly well-known as a serious pest of oyster-beds. A typical analysis of the meal shows 34 per cent protein, 16.9 per cent calcium and 0.43 per cent phosphorus.

In this experiment the starfish meal was compared with a commercial fish meal (analyzing 60% protein) as a supplement to a ration containing a high percentage of 44 per cent protein expeller soybean oil meal. The basal mixture common to all of the groups was composed as follows:

Crushed wheat.....	25
Pulverized oats.....	10
Dehydrated alfalfa meal.....	5
Iodized salt.....	0.5
B-Y feed.....	0.5
Delsterol.....	1 lb. per ton
MnSO ₄	4 oz per ton

The rations and chick weights at eight weeks of age are given in Table I. Twenty-five Single Comb White Leghorn chicks were started in batteries in each lot.

The results show that three per cent of starfish meal is equally as good as three per cent of the commercial fish meal, both of which showed significantly greater growth than the ration containing no animal protein. The average weights of the lot receiving six per cent of starfish meal are somewhat below the weights of the lot receiving only three per cent of starfish meal. The weights of the birds receiving a ration containing 12 per cent of starfish meal were very significantly lower than the weights of the birds receiving six per cent of starfish meal. Two birds (approximately 10%) in this lot showed definite

¹ The starfish meal was furnished by the Bingham Oceanographic Laboratory of Yale University, through the courtesy of Dr. Daniel Merriman.

TABLE I. SUPPLEMENTARY VALUE OF STARFISH MEAL AND FISH MEAL WHEN ADDED TO A SOYBEAN OIL MEAL RATION

Lot	Soybean oil meal		Fish meal		Starfish meal	
	1	2	3	4	5	6
<i>Ration</i>						
Basal mixture	41.0	41.0	41.0	41.0	41.0	41.0
Soybean oil meal	28.0	28.0	24.0	25.7	23.5	19.0
Starfish meal	....	....	....	3.0	6.0	12.0
Fish meal	....	....	3.0	....	....	....
Steamed bone meal	2.0	2.0	1.2	2.0	2.0	2.0
Ground limestone	2.0	2.0	1.3	....	....	....
Corn meal	27.0	27.0	29.5	28.3	27.5	26.0
<i>Composition (calculated)</i>						
Protein %	20.30	20.30	20.60	20.50	20.40	20.30
Riboflavin μ g/100 gm.	356.00	356.00	365.00	368.00	378.00	394.00
Calcium %	1.58	1.58	1.26	1.32	1.82	2.82
Phosphorus %	.70	.70	.69	.70	.70	.69
Ca : P. ratio	2.25 : 1	2.25 : 1	1.83 : 1	1.89 : 1	2.60 : 1	4.09 : 1
<i>Weight at 8 wks. (grams)</i>						
Males	692.0	638.0	769.0	768.0	718.0	467.0
Females	532.0	561.0	628.0	632.0	628.0	414.0
Male and female	612.0	600.0	699.0	700.0	673.0	441.0
<i>Mortality %</i>	16	16	4	0	0	16

perosis at the end of the experiment. It will be noticed also that the mortality was greater in this lot.

Discussion

The results of the rations containing three and six per cent of starfish meal are in agreement with those reported by Bird (1944). The three per cent level of starfish meal was just as effective as the three per cent level of commercial fish meal, although it furnished considerably less of the animal protein. Since the six per cent level of starfish meal shows less growth it would appear that five to six per cent of this product is probably the maximum amount that can be used in a chick starting ration. The very poor results obtained on the 12 per cent level of starfish meal no doubt were due largely to the excess calcium present in the ration which also greatly widened the calcium-phosphorous ratio.

Summary

Three per cent of starfish meal supplemented a mash in which soy-bean oil meal was the only high-protein feedstuff as effectively as three per cent of commercial fish meal.

The high calcium content of the starfish meal limits the amounts that can be fed to chicks. Six per cent is probably the maximum amount that can be used effectively.

REFERENCE

BIRD, H. R.

1944. Dehydrated pea vines and starfish meal in poultry feeds. *Poultry Science*, 23: 76.

PRELIMINARY REPORT ON EIGHT WEEKS OF COMPARATIVE FEEDING OF PROTEIN EQUIV- ALENT DIETS CONTAINING FISH MEAL, CRAB MEAL, AND STARFISH MEAL TO RHODE ISLAND RED CHICKS¹

BY ROY E. MORSE, FRANCIS P. GRIFFITHS, AND
RAYMOND T. PARKHURST

Massachusetts State College, Amherst, Mass.

Because of the war conditions there is a shortage of animal and marine protein for use in poultry and stock feeds. New sources and supplies of suitable protein are urgently needed. Starfish are abundant in Long Island Sound and adjacent areas and constitute a serious menace to the oyster industry. Because of the oyster losses they cause, it is frequently necessary for oystermen to spend time and effort removing the starfish from the oyster producing areas and killing them. At present there is no use for these starfish which are collected.

At the suggestion of Mr. J. Richard Nelson of the Warren Oyster Co., Warren, Rhode Island, work was undertaken to determine the composition and availability as a source of protein of a meal made from dried starfish. Mr. Ryan of The Dehydrating Process Co. of Boston very kindly cooperated by dehydrating 8,400 pounds of starfish to 2,100 pounds of starfish meal. This was used as a representative sample of what could be produced by commercial operations. Laboratory samples of starfish meal were also prepared and analysed.

One hundred and sixty, day-old chicks were separated into groups of 40 each and started on chick mash diets which had as a source of animal protein, comparative amounts of commercial fish meal, crab meal and starfish meal. A fourth group having eight per cent starfish meal was also started to act as a check on protein quality and possible toxic effects.

Most commercial feed mixtures contain not more than 2.5 per cent of fish meal, which provides about 1.4 per cent of animal protein in

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the diet. The remainder of the protein required is provided by meat scrap and grain products. It is interesting to note that the eight per cent starfish level diet did not contain any meat scrap.

An effort was made to balance the diets with respect to amounts of protein present and calcium-phosphorus ratio. Since starfish contain relatively large amounts of calcium with little phosphorus this was accomplished by the addition of CaH PO_4 to the starfish diet.

The actual ingredients and amounts used are shown in Table I.

Through the cooperation of Mr. Phillip Smith of the Feed Control Laboratory analyses were made of the completed diet.

Two lots of diets were mixed and the analyses of these diets are designated as one and two in Table I. Diets were quite uniform in composition. The largest variation was 1.4 per cent total protein between the first starfish and the first fish diets.

It is of interest to compare the analyses of the different protein sources, fish meal, crab meal, and starfish meal. Comparative analyses are shown in Table II.

Several samples of starfish meal prepared in the laboratory showed about five per cent higher protein and nearly 20 per cent lower ash. This was due to the unavoidable inclusion of small shells, etc., in the large amount (8400 lbs.) of starfish used for the trial commercial scale dehydration. Extraneous material was not present in the laboratory samples.

Results of Feeding Trials

The average weights of the day-old chicks was 38 grams. At the end of eight weeks the average weights for the different groups was as follows: fish meal 854 grams, 8 per cent starfish meal 816 grams, 4 per cent starfish meal 803 grams, crab meal 803 grams. The eight per cent starfish meal group weighed only four per cent less than the fish meal group and the other two groups were only six per cent under the top group in average weight.

The feed consumed for this period was 207.5 pounds for the fish meal group, 186.6 pounds for the eight per cent starfish meal group, 187.5 pounds for the four per cent starfish meal group, and 188.4 pounds for the crab meal group. The efficiency of feed conversion, pounds of feed fed per pound of weight gained, was 2.89 for fish meal, 2.87 for crab meal, 2.87 for four per cent starfish meal, and 2.86 for eight per cent starfish meal.

TABLE I. COMPONENTS AND ANALYSES OF DIETS USED

Components	<i>Fish</i> lbs. per 100	<i>Crab</i> lbs. per 100	<i>4% Starfish</i> lbs. per 100	<i>8% Starfish</i> lbs. per 100
Ground corn	25	25	25	25
Ground wheat	15	15	15	15
Ground barley	10	10	10	10
Bran	10	10	10	10
Dried distillers grain plus solubles	7.5	7.5	7.5	7.5
Meat scrap	2.5	2.5	2.5	....
Dried distillers solubles	2.5	2.5	2.5	2.5
Alfalfa leaf meal	6.25	6.25	6.25	6.25
Soy bean meal	15.0	15.0	15.0	15.0
Cod liver oil $\left\{ \begin{array}{l} 400D \\ 1000A \end{array} \right.$	0.2	0.2	0.2	0.2
Bone meal	1.5	1.0	1.0	....
Calcium carbonate	1.5	0.50	0.50	....
Salt	0.56	0.56	0.56	0.56
Manganese sulfate	12 grams	12 grams	12 grams	12 grams
Dicalcium phosphate	.....	.....	.....	2
Fish meal	2.50	.....	.....	.....
4 starfish meal	.....	.....	4.0	.....
8 starfish meal	.....	.....	.....	8
Crab meal	.....	4.0	.....	.....

Analyses:	I	II	I	II	I	II	I	II
Water	7.48	7.63	7.83	7.73	7.53	8.10	7.28	7.33
Protein	22.68	22.07	22.20	22.12	21.32	21.85	21.32	21.89
Fat	4.58	4.10	4.10	3.93	4.00	3.65	4.05	4.15
N. F. E.	52.38	51.80	51.89	51.69	53.85	51.12	51.58	51.42
Fiber	5.93	6.05	6.33	6.73	5.90	6.33	6.23	6.48
Ash	6.95	8.35	7.65	7.80	7.40	8.95	8.53	8.73

Individual examination and scoring of the chicks for feathering, leg color, and toe and foot dermatitis showed them to be approximately equal as to these qualities. Because of the high temperature of the brooder pens all of the chicks showed some retardation of feathering.

During the course of the experiment only four chicks out of the 160 started were lost through accidents and none through disease.

Forty chickens divided in two groups of 20 were continued on fish meal and eight per cent starfish diets until 14 weeks of age. Growth and feathering continued satisfactory and about equal for these groups.

From the results of this experiment it is evident that starfish meal is

TABLE II. COMPARATIVE ANALYSIS OF MEALS AS A SOURCE OF ANIMAL PROTEIN

	<i>Crab Meal</i>	<i>Starfish Lab. Sample</i>	<i>Starfish Commercial Meal</i>	<i>Redfish Meal</i>
	<i>in %</i>	<i>in %</i>	<i>in %</i>	<i>in %</i>
<i>Water</i>	4.35	3.11	2.10	6.5
<i>Protein</i>	31.22	33.63	27.54	56.6
<i>Fat</i>	3.12	7.7	5.3	8.6
<i>Fiber</i>	11.00	0.4	.....	.....
<i>Ash</i>	38.47	41.7	60.13	26.6
<i>Calcium</i>	16.43	15.14	.....	.....
<i>Phosphorus</i>	1.62	0.48	.....	.....
<i>Riboflavin</i>	16.9 ppm	8.9	.....	8.8
<i>Protein Quality</i>	56.6	65.28	58.9	78.9
<i>A</i>	.....	50 i. u.	.....	.....

equal to crab meal as a replacement for fish meal in poultry diets. Because of the higher ash content four pounds of either crab or starfish meal are required to replace 2.5 pounds of fish meal. If it is necessary to use as high as eight per cent starfish meal, allowance should be made for the high calcium and lack of phosphorus. When this was done starfish meal satisfactorily replaced both meat scrap and fish meal in the feed.

STARFISH MEAL FEEDING EXPERIMENT WITH CHICKS

BY R. C. RINGROSE

Poultry Department, University of New Hampshire, Durham, N. H.

Thirty Barred Plymouth Rock-New Hampshire crossbred chicks were started in each pen on June 15, 1943 and continued for six weeks. Individual chick weights and pen feed consumption records were made at two-week intervals.

Table I presents the percentage composition of the rations used. The analyses presented are based upon calculations from average analyses. However, the protein supplements were analyzed for protein and added on the basis of the actual analysis. Since the protein supplement and corn meal were the only variables in comparable rations, it is believed that the protein level in comparable rations was fairly close.

Growth and mortality results to six weeks of age are presented in Table II. At the lower level of protein feeding, starfish meal gave a growth response which was 83 per cent of that obtained with redfish meal or meat scrap. Growth results for pens 15 and 16 were normal.

The mortality in pen 11 occurred on the eighth and fifteenth days of the experiment and the cause could not be determined. One chick in pen 13 died on the thirty-first day of the experiment. Marked evidence of cannibalism was present but it could not be determined whether this occurred before or after death. No abnormalities were found on autopsy. A total of fifteen chicks in pen 14 died as follows: Sixth day 3; seventh day 6; eighth day 4; thirteenth day 1; fortieth day 1. Autopsy and cultures of various organs and tissues failed to show the cause of death. The one chick which died on the fortieth day exhibited symptoms of rickets before death, and upon examination showed evidence of poor bone formation. During the last two weeks of the experiment marked symptoms of rickets were present in this group.

Due to the high mortality of chicks in pen 14 during the first eight days of the experiment, seven replacement chicks from the same hatch were placed in this pen on the morning of the eighth day. These

TABLE I. PERCENTAGE COMPOSITION OF RATIONS

Pen Number	11	12	13	14	15	16
Ingredient	%	%	%	%	%	%
Yellow Corn Meal	48.25	52.25	51.25	29.25	39.25	37.25
Standard wheat middlings	15.00	15.00	15.00	15.00	15.00	15.00
Wheat bran	10.00	10.00	10.00	10.00	10.00	10.00
Ground oats	10.00	10.00	10.00	10.00	10.00	10.00
Starfish meal	9.00	.....	.....	18.00	.....	.....
Redfish meal	....	4.00	.....	.....	8.00	.....
Meat scrap	....	....	5.00	.....	.....	10.00
Soybean oil meal	.....	.....	.....	10.00	10.00	10.00
Alfalfa leaf meal	5.00	5.00	5.00	5.00	5.00	5.00
Fermentation by-product	1.00	1.00	1.00	1.00	1.00	1.00
Fortified cod-liver oil	.25	.25	.25	.25	.25	.25
Salt and manganese	.50	.50	.50	.50	.50	.50
Steamed bone meal	1.00	.....	.....	1.00	.....	.....
Pulverized limestone	....	2.00	2.00	....	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

Calculated analysis

Per cent protein	13.15	13.11	13.15	18.46	18.45	18.53
Per cent calcium	1.92	1.20	1.35	3.39	1.15	1.45
Per cent phosphorus	.61	.59	.67	.67	.79	.93

Starfish meal, redfish meal and meat scrap analyzed for protein and added on basis of actual analyses.

TABLE II. GROWTH AND MORTALITY RESULTS AT STATED INTERVALS

Pen Number	13% Protein			18.5% Protein		
	11	12	13	14	15	16
	gms.	gms.	gms.	gms.	gms.	gms.
Initial weight	40	39	39	39	40	41
2 weeks	67	75	74	56	106	110
4 weeks	123	148	144	105	296	296
6 weeks	209	254	252	170	521	539
Chicks per pen-number	30	30	30	30	30	30
Total mortality-number	2	0	1	15	0	0

chicks had been maintained during the first week on a ration containing a blended fish meal. The ration supplied 13 per cent of total protein. None of the replacement chicks died during the course of the experiment. Thus, beginning on the eighth day pen 14 contained 24 chicks with the loss of one on the thirteenth day and one on the fortieth day.

Table III presents the data from the feed consumption records.

TABLE III. FEED CONSUMPTION IN POUNDS AT STATED INTERVALS

Pen Number	11	12	13	14	15	16
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
0-2 weeks	9.25	9.75	11.25	6.25	12.00	12.25
2-4 weeks	27.75	29.00	28.25	17.50	33.75	36.50
4-6 weeks	22.75	29.00	26.25	16.50	50.75	50.00
Total	59.75	67.75	65.75	40.25	96.50	98.75
Pounds feed per pound of gain	5.84	4.78	4.87	7.14	3.00	3.03

Discussion

The high calcium content of starfish meal offers a special problem which is more troublesome than at first appears. The poor growth results and ricketic condition exhibited by pen 14 was undoubtedly due to the high calcium content and wide calcium : phosphorus ratio of the feed used. Whether the high mortality exhibited during the first week of the experiment was due to the high calcium content and/or the wide calcium : phosphorus ratio is not known. The common phosphorus supplements such as steamed bone meal and tricalcium phosphate are of no value in supplying additional phosphorus since in each case the calcium : phosphorus ratio is about 2 : 1. Monocalcium phosphate or other high phosphorus carrier would be needed to bring the calcium : phosphorus ratio into balance. Such a high phosphorus carrier was not available here at the time of the experiment. Since nothing was known of the availability of the calcium in the meal, although it seemed unlikely that it would be unavailable, it was decided to formulate the ration as shown.

The calcium : phosphorus ratio of the ration of pen 11 is also somewhat wider than is commonly used in practice (2 : 1), although experimental evidence indicates that with adequate vitamin D and reasonable levels of calcium and phosphorus in the ration, the calcium : phosphorus ratio may vary between 1-3 : 1.

Summary

At a level of 13 per cent protein in the total ration, starfish meal gave a growth response which was 83 per cent of that obtained with redfish meal or meat scrap.

STARFISH MEAL AS A PROTEIN SUBSTITUTE IN CHICK RATIONS

BY H. O. STUART AND C. P. HART

R. I. Agricultural Experiment Station,¹ Kingston, R. I.

In line with the criticalness of the feed situation during the past year, investigators in many parts of the country have sought to determine the utilizability of many products in poultry feeding which have received scant or no attention in the past. Because of the difficulty of securing adequate quantities of protein concentrates, an effort was made to determine the feasibility of utilizing starfish meal as a substitute for protein concentrates normally found in rations. Furthermore, the lowly starfish has presented a problem of no mean proportions to the oyster industry. Any effort, therefore, looking forward to the utilization of starfish meal is of concern to both the poultry producers and the fishing interests.

Ground, air-dried starfish meal was furnished by the Bingham Oceanographic Laboratory for the purposes of this test. One hundred day-old chicks were divided equally for comparative feeding trials with one group receiving the currently used ration and the other group receiving this ration substituting starfish meal for other protein concentrate and adjusting the ration for calcium content. These adjustments were essential in view of evidence that dried starfish meal contains approximately 34 per cent protein and 42 per cent calcium carbonate. These adjustments are evident in Table I.

TABLE I. COMPOSITION OF RATION

<i>Ingredients</i>	<i>Check Ration</i>	<i>Starfish Meal Ration</i>
<i>Yellow Corn Meal</i>	170 lbs.	165 lbs.
<i>Ground Barley</i>	60	60
<i>Flaked Wheat</i>	250	250
<i>Ground Oats</i>	250	250
<i>Fish Meal, 60% protein</i>	70	45
<i>Meatscraps, 50% protein</i>	40	40
<i>Starfish Meal</i>	...	40

¹ In co-operation with the Bingham Oceanographic Laboratory, Yale University.

TABLE I. COMPOSITION OF RATION—*Continued*

<i>Ingredients</i>	<i>Check Ration</i>	<i>Starfish Meal Ration</i>
<i>Dried Yeast</i>	20 lbs.	20 lbs.
<i>Alfalfa Meal, 12% protein</i>	40	40
<i>Soybean Meal, 43% protein</i>	80	80
<i>Cod Liver Oil</i>	4	4
<i>Ground Limestone</i>	10	...
<i>Common Salt</i>	6	6

In view of the fact that the rations above were determined by calculative process, chemical analyses were conducted to determine the analytical comparisons of the rations used based on uniform samples collected from each individual mixture.

TABLE II. ANALYSES OF FEED* (in per cent)

<i>Ingredients</i>	<i>Check Ration</i>	<i>Starfish Meal Ration</i>
<i>Protein</i>	21.44	21.10
<i>Fat</i>	4.34	4.53
<i>Crude Fiber</i>	4.86	5.19
<i>Nitrogen-free extract</i>	54.40	53.24
<i>Ash</i>	6.53	7.41
<i>Moisture</i>	8.43	8.53
<i>Calcium</i>	1.25	1.49
<i>Phosphorus</i>	0.87	.89

* Analyses by J. B. Smith, R. I. Experiment Station.

Examination of the above table demonstrates that the rations utilized were relatively comparable and that both were sufficiently high in protein content to produce substantial growth.

Growth was determined by weighing each group at two-week intervals throughout the 12-week experimental period. No effort in the beginning was made to segregate male and female weights, but at the completion of the test cockerels and pullets were segregated for this purpose. It will be noted in Table III that while the chicks which were fed the check ration grew at a somewhat faster pace up to and inclusive of 10 weeks of age, this advantage was lost by the time the chicks attained 12 weeks of age. Interestingly enough, the check ration group had a larger percentage of cockerels than was to be found in the starfish meal group. Interesting also is the fact that the cockerels in the check ration group were slightly heavier than those in

the starfish meal ration group, and that the reverse was true when the weights of pullet chicks were considered. However, these differences are not necessarily significant when studied on a feed efficiency basis.

TABLE III. GROWTH OF CHICKS (in pounds)

<i>Average Weight</i>	<i>Check Ration</i>	<i>Starfish Ration</i>
<i>1st day</i>	.0900	.0900
<i>2nd week</i>	.2812	.2816
<i>4th week</i>	.6500	.6428
<i>6th week</i>	1.2666	1.2183
<i>8th week</i>	1.8668	1.7612
<i>10th week</i>	2.6166	2.4612
<i>12th week</i>	3.0395	3.0877
<i>Average weight of cockerels</i>		
<i>at 12th week (25 cockerels)</i>	3.4200	(21 cockerels) 3.3619
<i>Average weight of pullets</i>		
<i>at 12th week (23 pullets)</i>	2.6260	(28 pullets) 2.8821

Examination of Table IV presenting an over-all picture of total gain in weight and total feed consumption reveals that chickens receiving the check ration utilized feed to a minor degree more efficiently than the test group receiving the starfish meal ration.

TABLE IV. FEED EFFICIENCY

	<i>Check Ration</i>	<i>Starfish Meal Ration</i>
<i>Total gain in weight for 12-week period</i>	141.4 lbs.	146.8 lbs.
<i>Total feed consumption for 12-week period</i>	660.0 lbs.	691.5 lbs.
<i>Pounds of feed for one pound of gain in weight</i>	.4667	.4710

In view of the high calcium content of starfish meal and the attendant adjustments in the ration, it was deemed advisable to secure analyses of tibia bones of representative numbers of chickens fed the comparative rations as an indication of physiological utilization.

TABLE V. ANALYSES OF TIBIA BONES*

(Calculated on a fat-free, moisture-free basis)

	<i>Check Ration</i>	<i>Starfish Meal Ration</i>
<i>Per cent Calcium</i>	25.70	27.94
<i>Per cent Phosphorus</i>	9.15	9.22
<i>Per cent Ash</i>	48.75	49.80

* Analyses by J. B. Smith, R. I. Experiment Station.

Table V reveals that the chickens fed the starfish meal ration had a higher calcium, phosphorus, and ash content of bone structure as judged on the basis of tibia analyses. This difference may be partially accounted for by a somewhat higher mineral content of the starfish meal ration as quantitatively determined and shown in Table II. However, it does demonstrate that the mineral values of the ration were utilizable by the chickens for bone development.

Conclusions

Under conditions of this test the following conclusions are drawn:

1. Starfish meal may be used satisfactorily as one of the protein concentrates in chick rations.
2. Starfish meal can be utilized in place of fish meal by making appropriate adjustments in the ration.
3. A comparatively satisfactory growth can be secured to 12 weeks of age where starfish meal is used as a protein concentrate.
4. Starfish meal rations carefully compounded will produce weight gains per pound of feed consumed in line with established rations.
5. The starfish, which has consistently presented a problem to the oyster industry, can serve a useful purpose in meeting an important feeding problem.
6. The calcium content of starfish meal is utilizable for bone development.

THE USE OF STARFISH MEAL IN CHICK DIETS

BY DONALD WHITSON AND HARRY W. TITUS

*Bureau of Animal Industry
Agricultural Research Administration
United States Department of Agriculture
Beltsville Research Center
Beltsville, Maryland*

The shortage of feedstuffs that has resulted from the increase in the production of livestock, has stimulated the recovery and maximum utilization of materials that formerly were discarded or poorly utilized. One such material is starfish. This common marine invertebrate is a serious pest of oysters and is taken in a considerable quantity in the cleaning of oyster beds.

This paper reports the results obtained in three experiments that were conducted between September 1943 and January 1944 for the purpose of ascertaining whether or not starfish meal can be used advantageously in the feeding of growing chicks.

Experimental

The starfish meal used in the experiments here reported was produced experimentally by grinding sun-dried whole starfish and was supplied by Dr. Daniel Merriman, of the Bingham Oceanographic Laboratory, New Haven, Connecticut. The proximate partial composition of the material was:

<i>Moisture</i>	5.5 per cent
<i>Crude protein</i>	30.7 per cent
<i>Fat (ether extract)</i>	4.5 per cent
<i>Crude fiber</i>	1.9 per cent
<i>Ash (900° C.)</i>	30.0 per cent
<i>Calcium</i>	17.6 per cent
<i>Phosphorus</i>	.35 per cent

The basal diet was compounded as follows: ground wheat, 26.9; ground yellow corn, 25.0; soybean meal, 35.0; alfalfa leaf meal, 8.0; B-Y riboflavin supplement (110 micrograms riboflavin per gram), 2.0; steamed bonemeal, 1.0; ground limestone, 1.0; manganized salt, 1.0; and vitamin D powder (1000 A. O. A. C. Units per gram), 0.1.

In diets 1 to 7 various quantities of ground wheat, soybean meal and ground limestone were replaced by starfish meal and sardine fish meal. In diets 8, 9, and 10, a portion of the soybean meal was replaced by corn and wheat in order to have diets that would make possible a more critical study of the quality of the protein. In these experiments, diets 1, 2, 3, 6, and 7, each contained approximately the same quantity of protein, calcium and phosphorus. Diets 4 and 5 contained considerably more calcium because of the high calcium content of the starfish meal. In the third experiment, monocalcium phosphate was used as a phosphorus supplement in order to obtain a satisfactory ratio of calcium to phosphorus in a diet containing a large amount of starfish meal. Thereby, diets 9 and 10 containing three per cent sardine fish meal and 7.5 per cent starfish meal, respectively, were formulated to contain 2.00 per cent calcium and 1.06 per cent phosphorus.

In the first experiment 25-day-old White Leghorn chicks were used per lot and in the second and third experiments 25 day-old Rhode Island Red chicks were used per lot. The chicks were brooded in batteries in air conditioned rooms.

Results

The modifications of the basal diet, and results of the three experiments are summarized in Table I. In the first experiment the average live weight of the chicks in the lot receiving eight per cent of starfish meal was less than that of the other three lots at six weeks. There were no significant differences between the average live weight of the chicks that received the basal diet and that of the chicks that received the diets containing two per cent of sardine fish meal or four per cent of starfish meal, in either the first or second experiments. The chicks receiving the diet containing 12 per cent of starfish meal were significantly smaller than the chicks receiving four per cent of starfish meal or two per cent of sardine fish meal in their diet. These two experiments indicate that the high calcium content of starfish meal limits the quantity of starfish meal that can be utilized in chick diets.

In the third experiment chicks receiving the diet containing 2.5 per cent of starfish meal replacing limestone and wheat were significantly larger than the chicks receiving the diet containing one per cent of sardine fish meal replacing wheat. The chicks receiving diet 8, in which a portion of the soybean meal in the basal diet was replaced by

TABLE I. EFFECT OF STARFISH MEAL ON THE GROWTH OF CHICKS

Diet Material No. Added	Modifications of Basal Diet Material Replaced	Average 6 Week Live Weights			
		First* Experi- ment	Second* Experi- ment	Third* Experi- ment	Av. Mortal- ity
		Grams	Grams	Grams	%
1 None	None	362.6	374.2	.....	0
2 2% sardine fish meal 1% wheat	3% soybean meal	384.7	400.6	.....	2
3 4% starfish meal	3% soybean meal 1% limestone	376.2	398.7	.....	2
4 8% starfish meal	6% soybean meal 1% limestone 1% wheat	339.9	296.9	.....	6
5 12% starfish meal	6% soybean meal 1% limestone 5% wheat	.....	242.6	.....	16
6 1% sardine fish meal	1% wheat	.....	.....	406.8	4
7 2.5% starfish meal	1% limestone 1.5% wheat	.....	.....	450.2	24
8 9.6% wheat .4% bonemeal 10.0% corn	20% soybean meal	.....	.....	212.1	4
9 3.0% sardine fish meal 2.9% bonemeal .5% monocalcium phosphate 3.6% wheat 10.0% corn	20% soybean meal	.....	.....	343.4	12
10 7.5% starfish meal 3.0% monocalcium phosphate 1.5% wheat 10.0% corn	1% limestone 1% bonemeal 20% soybean meal	.....	.....	350.8	4

* The difference in average live weights between any two lots required for statistical significance (odds of 19.1) was 37.8, 33.2 and 35.9 grams for the first, second and third experiments, respectively.

corn and wheat, attained an average six week weight of about one-half that normally attained by chicks receiving this basal diet. The addition of 7.5 per cent of starfish meal or three per cent of sardine fish meal to the basal mixture in which a portion of the soybean meal was replaced by corn and wheat, increased the average live weight of the chicks receiving those diets by more than 60 per cent, but did not bring the weights up to the normal weights attained on the basal diet.

The use of starfish meal in the diets had no apparent effect on the mortality of the chicks, with the possible exception of diet 5 used in

experiment 2, in which the excess calcium supplied by 12 per cent of starfish meal greatly depressed the growth.

Discussion

The results of these three experiments show that starfish meal is a satisfactory feedstuff for supplying calcium and some protein to chickens. The sun-dried starfish meal used in this experiment was of good quality. However, machine drying would be essential for routine commercial production of a starfish meal of similar quality. In these experiments the starfish meal appeared to supply protein of about the same quality as that supplied by sardine fish meal. In addition, the starfish meal when used to supply the same amount of protein appeared to contain the same growth stimulating effect as the sardine fish meal. The growth stimulating action appears to be due to the quantity of certain amino acids or vitamins present. These results confirm those of an experiment reported by Bird (1944), in which starfish meal was found to be comparable to a commercial menhaden fish meal in its ability to supplement a mash containing no animal protein. Since most chick diets contain 1 to 2 per cent calcium carbonate (high calcium limestone or oyster shell) the substitution of 2.5 to 5 per cent of starfish meal would supply the same quantity of calcium and at the same time supply .75 to 1.5 per cent of protein of animal origin. In view of the present shortage of protein supplements of animal origin, the production and use of starfish meal should be encouraged.

Summary

Starfish meal, produced by drying and grinding whole starfish, was found to contain 30.7 per cent protein, 17.6 per cent calcium and .35 per cent phosphorus. In three experiments it was compared with sardine fish meal at the same protein levels as a supplement to a basal diet containing no animal protein. The starfish meal gave as good results as the sardine fish meal when the quantity used did not supply an excess of calcium. The quantity of starfish meal that may be used in practical chick diets is limited to 2.5 to 5.0 per cent of the diet by its high calcium content.

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BIRD, H. R.

1944. Dehydrated pea vines and starfish meal in poultry feeds. *Poultry Science*, 23: 76-77.

THE CONTROL AND UTILIZATION OF STARFISH IN RHODE ISLAND WATERS

BY HAROLD N. GIBBS

*Fish and Game Administrator, Department of Agriculture and Conservation,
Providence, R. I.*

The control of starfish is such a vital factor in oyster cultivation, and the two are so intimately connected, that any consideration of one must of necessity include the other.

Rhode Island has a very direct interest in the oyster industry and its related problems. The leasing of grounds for the propagation of oysters has been in effect for about 145 years, the first leases by special acts of the General Assembly.

In 1844 the Legislature created a commission for that purpose and the procedure has continued ever since. In 1935 the duties of several commissions were combined in the present Division of Fish and Game.

In reading the Annual Reports of the Shellfish Commission from 1900 to the present, as well as the earlier manuscript records dating back to 1862, there is one subject that occurs most frequently—the periodic outbreaks of starfish and the time and money expended by the growers in their continuous warfare on these enemies of the oyster.

As a case in point, we read in the Report for the year 1900, "Some growers have kept from one to three steamboats employed all the time in protecting the beds"; and again, in the 1914 Report, "The oyster set was destroyed by Starfish as well as large quantities of one and two year old oysters." The prevalence of starfish is noted in practically every report, and many oyster growers were obliged to cancel much of their holdings following such invasions, which represented the loss of thousands of dollars of state revenue.

Exact figures are difficult to obtain. While it is true that all oyster companies keep accurate records, and although the time spent by boats and men engaged in starfish control is known, the amount of stars destroyed can only be estimated. One concern, The Narragansett Bay Oyster Company, recorded the number of pounds brought in over a period of years. While these figures are important they fail to give a clear picture of conditions, since other factors, such as the

number of boats employed and the type of ground worked do not appear in the records. However, the fact that in every year there was an abundance of starfish is most evident.

The reason why more data are not available is explained in part by the nature of the work itself. The objective is to reduce the number of starfish whenever they appear as quickly as possible, and by any method. There are times when the stars invade the beds in such quantities that oyster dredges are used. Scattered individuals, distributed over a large area, are caught with "mops," an iron framework to which thread or twine tangles are attached at regular intervals. In using mops, starfish are either picked off by hand or the mops are immersed in a tub of heated water, the dead stars falling off when the mop goes over. Within the last few years an application of lime has been used to destroy the stars on the beds.

In 1940-41 there was an unusual outbreak of starfish in Narragansett Bay and much of the "public" ground was heavily infested. The oyster growers could not keep ahead of the overflow of stars from adjacent areas.

In 1941 the Legislature appropriated the sum of \$12,500 for starfish control and actual work began on April 22 of that year, as soon as the funds were available. Every effort was made to destroy as many stars as possible before the spawning season.

The work was done on a "bounty" basis, the fishermen being paid at the rate of 75 cents per hundred pounds and the stars were offered to local farmers, gratis, for use as fertilizer. All dredging was confined to the public grounds.

From April 22 to May 23, when the funds were exhausted, a total of 1,211,064 pounds of starfish were delivered to the two receiving stations. Approximately 35 boats were licensed to dredge and about half that number were employed continuously. Many of these boats brought in from three to four tons of stars daily. The starfish population was reduced, but there still existed many areas that had not been touched.

In 1933-34 there was a C. W. A. Project to reduce starfish, but the figures are not available to the writer.

In connection with the work in 1941 it is interesting to note that the local farmers who used the raw stars for fertilizer reported excellent results. Analysis of these same stars compared unfavorably even with the poorest grades of commercial fertilizer. We know that in the

orchards where starfish were applied the apples were highly colored, probably from the lime content of the stars, but possibly from some additional mineral present. We also know that on other lands where raw stars were placed the grounds continued to produce good crops without any further application of fertilizer. Is it possible that trace elements, too minute to appear in an ordinary analysis, may be responsible? At least the idea is worth further investigation.

There can be no question that we have an ample supply of starfish in our Rhode Island waters and it is equally evident that there must be a rigid control of the population if oyster culture is to be successful. Some means of utilizing the stars should be found. At the moment two methods are suggested—as a fertilizer or as a poultry or animal food.

The ideal solution would be to find a use whereby a price could be paid the fisherman at a level that would induce them to catch them in quantities, to create a demand for the product, and to establish a processing plant near the source of supply.

While the oyster companies do produce an appreciable amount of starfish in the course of a year, it is our opinion that if they are to be utilized to any extent commercially, or if the starfish are to be materially reduced, it will take the combined efforts of both the oyster grower and the fisherman to produce results.

The possibility of exterminating the starfish will be our last concern.

OBSERVATIONS ON THE OCCURRENCE AND POSSIBLE USES OF STARFISH

BY J. RICHARDS NELSON

Warren Oyster Company, Warren, R. I.

The starfish is an enemy that must be reckoned with continuously by the oyster planters of New England and New York. Oysters in Delaware Bay are occasionally attacked by this pest and the last serious invasion of the oyster beds occurred in 1930 during a period of dry weather and high salinity. Chesapeake Bay planters report trouble with starfish where they plant nearest the Capes, but they do not experience any difficulty in the lower salinity areas of the Bay and in the several rivers where oysters are produced.

In the North Atlantic area the worst trouble is experienced in Long Island Sound from Norwalk to Branford, Connecticut. This is the main oyster seed producing area of the North and starfish set on practically all of the beds where oyster seed is produced. In general, the starfish set occurs just before the oyster set so that the young stars are just the right size to devour the young oysters. Narragansett Bay and Buzzards Bay have starfish in large numbers and this is an important factor in keeping oyster production low in these two bays.

In Gardiners Bay, Shelter Island Sound and in the Peconic Bays there are some of the best oyster growing and maturing grounds in the North. Oysters do not generally set in these bays but do grow and fatten exceptionally well. Starfish occur throughout this area but are generally not a serious menace except in Great Peconic Bay from Robbins Island to Jamesport. This is contrary to the general rule that starfish are found only where the salinity is highest.

Considerable work has been done in recent years on the control of starfish through the use of lime. This seems to work out well in experiments but has not proved satisfactory so far to the commercial grower. The most effective method for the commercial grower is still the use of mops which are brought up to the deck of the boat and immersed in hot water. Dredging of starfish on vacant bottom is also

effective and is commonly done by oyster planters when the presence of this enemy has been discovered.

From the observations of the writer over a period of years, it appears that starfish move quite rapidly under certain conditions and travel to sources of food. Experiments at the Milford Laboratory showed no evidence that stars had any way of determining the location of food, but repeated experience has taught us in the oyster industry that this pest will travel several miles in as many months and find our beds of seed oysters in Long Island Sound. It is difficult to believe that this is the result of mere chance.

The writer's experience in the utilization of starfish has been confined to their use as a fertilizer on various crops. They are particularly suited to the crops that require a high nitrogen fertilizer and that thrive in an alkaline soil. Excellent results have been obtained by spreading the starfish on the ground in March, approximately one layer thick, and plowing these under. The effect is more noticeable the second season, apparently due to the fact that stars plowed under in the spring probably do not become available for at least six weeks or more, and also because plowing usually puts them below the level where most plants can utilize them. Plowing the following year brings them on top and they are thoroughly incorporated in the soil. Such crops as corn, lettuce, cabbage and all leaf crops thrive on stars. Root crops such as beets and carrots do well the second year, but potatoes do not do well with this fertilizer, probably due to the fact that it is unbalanced, being heavier in nitrogen. Also, the lime content tends to promote scab.

Commercial use of starfish depends, in the writer's opinion, on developments which will make it sufficiently profitable to gather them for sale. No industry could be built on the supply received from oyster boats engaged in taking starfish only when they threaten oyster crops. If starfish meal were as valuable as fish meal it is probable that fishing boats could be induced to gather starfish as a business.

In regard to the supply, it appears that this is great enough to support several fish meal plants if the value of the product were great enough to attract commercial fishermen.

STARFISH PREVALENCE AND PRODUCTION PROBLEMS

BY H. GORDON SWEET

Henry C. Rowe Trust, New Haven, Connecticut

INTRODUCTION

Oyster growers have caught immense quantities of starfish over a period of more than one hundred years in their efforts to protect their crops from these animals. This starfish material has served no useful purpose except in a few instances where farmers have been willing to cart it away for fertilizer. In a period of stock feed and fertilizer shortages the possible value of starfish has obvious significance.

The present report is a discussion of some of the production problems to be considered and solved. It is based on data compiled by H. C. Rowe & Company, which propagates oysters in Long Island Sound and produces market oysters in Gardiners Bay and Shelter Island Sound at the eastern end of Long Island.

ABUNDANCE OF STARFISH

The primary concern of the oyster grower is to protect his oysters from the ravages of starfish. The catch of starfish in pounds or tons is of secondary importance. This should be borne in mind in connection with the present report, which is based on operations concerned with the conserving of oyster crops rather than the harvesting of a maximum volume of starfish.

Starfishing is not necessarily carried on in the areas of greatest infestation because the oysterman's first concern is to give maximum protection to his youngest crops.

The preparation of production areas for the planting of dock shells to which the young oysters will attach themselves involves the elimination of all starfish from the beds themselves and from adjacent areas. This operation must be carried out, even though the starfish prevalence is as low as 10 pounds per hour per boat. After the crop of young oysters has appeared, adjacent areas must be constantly watched for the approach of starfish.

These surveys consume many days in every year and are not concerned with a heavy production of starfish, which is the last thing the grower wishes to find on or near his oyster beds.

As crops reach the ages of two, three and four years, they are less vulnerable to destruction by starfish and require less vigilant inspection and care.

It is seldom possible for an oyster grower to send out one of his starring boats with the single objective of finding a maximum concentration of starfish for capture and use as a by-product.

Hence, this report does not indicate the maximum quantity of starfish which might be obtained by vessel units which were released from the necessity of protecting specific ages of oysters and the localities on which they were planted.

The general practice in the oyster industry is to capture starfish with the use of mops or tangles, as described in a previous paper in this series (Gibbs).

The Rowe Company operates two boats for its starring protection, with occasional assistance from larger units. These two boats are the *RIVAL* and the *SEA GULL*. The *RIVAL* is used for inspection and surveys, while the *SEA GULL*, which is equipped with a steam boiler and tubs containing hot water in which the mops are immersed, is called upon to combat stars in areas which are known to be infested.

The *SEA GULL*, therefore, catches many more starfish than the *RIVAL* in the course of a year, and the figures given relate to the *SEA GULL'S* catch. This vessel is an open-deck Diesel unit of 13 gross tons, 50 feet in length, and equipped with a 40-horsepower Fairbanks-Morse engine. The star frames are raised and lowered with chains operated by hoisters in the hold of the vessel which connect with the main engine. The two iron frames, with their trailing mops of cotton yarn covered with starfish, are hoisted to the deck and dipped in the hot water tubs for approximately two minutes at a temperature of 150° F. The frames are then returned to the water and the cooked starfish, which have become soft, drop off while the gear is being returned to the bottom.

The *SEA GULL* is manned by a Captain and two deckhands. Her operating cost is roughly \$30 a day or \$750 a month.

The area over which this vessel operates comprises somewhat more than 3,000 acres of oyster grounds located off the Connecticut coast between Branford and Stratford. These areas consist of production

beds where young oysters first appear in the summer, extensive growing areas for oysters of different ages, vacant grounds, worthless soft bottom and reefs.

In certain places, such as the vicinity of breakwaters, starfish are always present in appreciable numbers. When an oyster grower is not obliged to fight starfish on the oysters themselves, he first cleans up adjacent areas, and then has a few days or weeks in every year when he can work out from cultivated areas and attack starfish wherever they are concentrated. It is seldom possible to work these areas of maximum abundance because starfish are highly mobile and are constantly threatening to invade the beds where oysters are planted.

The following summary gives a generous estimate of the number of starfish taken each month during the year 1942, based on a 25-day month of 7-hour days. These data were obtained from a live-weight record of pounds per hour caught by the *SEA GULL* in the course of her protection of the Rowe oyster beds.

TOTAL MONTHLY CATCH OF STARFISH BY THE *Sea Gull*

Date	Lbs. Live Starfish
January, 1942.....	3,311
February, 1942.....	4,452
March, 1942.....	3,492
April, 1942.....	3,676
May, 1942.....	4,232
June, 1942.....	3,465
July, 1942.....	2,682
August, 1942.....	2,575
September, 1942.....	7,079
October, 1942.....	33,268
November, 1942.....	31,597
December, 1942.....	22,808
January, 1943.....	8,091
Total	130,728

The above catch of live starfish is estimated to be about five per cent of the total catch from the oyster-producing areas in Long Island Sound between Branford and Bridgeport. From this it appears that the total annual catch for 1942 in this section amounted to roughly $2\frac{1}{2}$ million pounds, live weight.

From January 1942 through August 1942 there were moderate quantities of starfish on or near valuable crops. The quantity and

location of these animals was sufficient to justify the use of the *SEA GULL* in these areas, although the total catch was not high.

In September, 1942 the starfish population was very active, and the rise in poundage reflects encroachment upon crops of young oysters.

In October, the Rowe Company encountered the worst general invasion of starfish ever observed, and the *SEA GULL* spent the month working on heavy beds of stars, catching as high as 800 pounds per hour live weight.

In November the situation was still critical but slightly improved, owing to the fact that starfish become inactive during the winter months.

In December there was a noticeable decrease in the total weight, indicating that the *SEA GULL* was in control of the situation. This was further apparent in January, when the catch declined to 8,091 pounds.

DISCUSSION

A few farmers in Connecticut have used starfish on the soil as fertilizer for many years, but have been willing to pay little or nothing for the starfish material.

If these animals are to be used commercially as poultry feed, fertilizer, or otherwise, a careful study of production and handling problems will be necessary before the material can be made available.

The oyster grower would be glad to sell his starfish even though the price received did not cover his cost, since these animals must be caught in any case. With a price of \$10 per ton for live starfish, the maximum monthly income from stars taken by the *SEA GULL* in 1942 would have been \$166 for October, when the greatest catch was made. This is a small remuneration considering the cost of operating the boat, which was \$750 for the month. Moreover, the high catch in this month depended on the use of hot water tubs in which the stars were cooked and then left in the mops for dispersal in the water. If these starfish had been picked off the mops by hand, the catch per hour would have been reduced and the income from starfish in that month would have been less than \$166.

A new method of removing the starfish from the mops might be devised, but success in this direction is highly problematical. It is possible that a trawl could be designed for capturing starfish on

vacant bottoms. This gear could not be used on oyster beds because of the certain damage which would be inflicted on the growing oysters.

Other types of small fishing vessels might be used to good advantage in this work provided a price commensurate with the effort and cost of operation were received. It is possible that these boats might earn a good living at certain seasons fishing primarily for starfish.

If starfishing were developed in any section, the landing of these animals would be the next consideration. They could be brought to one shore station, or might be delivered to a "buy-boat" out on the water. The establishment, maintenance and operation of a shore plant for receiving and processing starfish for shipment is a separate problem which could be solved without too much difficulty or investment.

In summary, the following considerations are presented:

1. The financial return to an oyster boat in Long Island Sound catching starfish as a by-product of the protection of oyster crops would not be more than a fraction of the operating cost.

2. The financial return to an oyster boat in Long Island Sound operating to catch a maximum tonnage of starfish without regard for the protection of specific oyster beds would not be profitable, although an oyster grower would willingly operate in this manner when his crops were not in danger if he had a convenient place of delivery.

3. The financial return to an oyster boat in Long Island Sound using new methods of starfishing, such as trawling, with the object of making a profit out of the operation, would not be adequate, in the writer's opinion, but should be investigated. In periods when equipment and labor are available, progressive oystermen might be willing to experiment along this line, even though they do not expect the receipts to equal the cost.

4. The use of other small fishing vessels to take starfish commercially depends on an assured market, a receiving station and a stable and adequate price. In view of the fact that prices as high as \$14 per ton of live starfish have been quoted recently, it is conceivable that human enterprise may be attracted to the capture, processing and utilization of this marine organism.

STARFISH MENACE IN SOUTHERN MASSACHUSETTS IN 1931

EARNEST W. BARNES

Biologist, Marine Fisheries Division, Massachusetts Department of Conservation

In 1931 the then newly-created marine fisheries section of the Massachusetts Department of Conservation was suddenly confronted with an alarming menace to the shell fisheries caused by the inroads of immense numbers of starfish which threatened to wipe out the valuable bay scallop, oyster and quahaug fisheries along its entire southern coastline from the Rhode Island State line to Monomoy Point. These shell fisheries were valued in excess of \$2,000,000. Upon their success depended the welfare of sixteen coastal towns whose principal income came from these fisheries; they furnished a livelihood for over twelve hundred fishermen. As is not infrequently the case in State fisheries, although a solution of this problem was exceedingly urgent no adequate precedent had been established. The whole problem constituted a direct challenge to the biological staff and was so accepted.

The facts in the situation were these:¹

A coastline in excess of one hundred miles was affected by starfish with the greatest concentration centered in Buzzards Bay and the neighboring waters of Nantucket and Vineyard Sounds. As evidence of the concentration of stars reported at the time, we may cite the efforts of two or three towns which had attempted individually to suppress them. These efforts are exemplified by the experience in Wareham in March, 1931, where a town appropriation of \$1,000 was used up in one day and a second similar appropriation in three and one-half days. One fisherman working alone in this town brought in 88 bushels of starfish in one day, which represented approximately 26,400 stars. This amount, large as it is, was exceeded many times in later work.

The bay scallop public fishery in the general area had dwindled

¹ See Annual Reports of the Division of Fisheries and Game, Department of Conservation of Massachusetts, for 1932-36.

progressively from an estimated \$750,000 revenue in 1929 to about \$200,000 in 1933; and in the town of Wareham from \$200,000 to \$1,000.

The oyster fisheries in this area are conducted as private fisheries, and although they were very hard-hit by the menace, the companies were equipped with "cotton mops" or "tangles," and by systematic work were able to reduce, somewhat, the amount of destruction. They were, however, troubled by the migration of stars from neighboring public areas.

Injury to the public quahaug fishery resulted from the smothering effect of concentrated mats of starfish.

The principal ray of hope came from a realization by civic leaders of the seriousness of the situation, but this was also offset by a multiplicity of remedies and a pessimism as to results. Through the support of the affected towns an appropriation of \$15,000 was obtained in 1932 from the General Court to be spent under the direction of the State Department and in accord with its rules. Subsequent appropriations amounting in total to \$30,000 were made, and by 1936 we considered that the number of starfish had been reduced to such an extent as no longer to be considered a menace. Under the plan adopted each town was required to contribute a certain amount of money toward the project conducted in its waters. This amount was agreed upon in advance on the basis of need as determined by the State but could not be less than one-quarter of the total amount spent. The towns were further asked to adopt a regulation requiring the fishermen to bring ashore all starfish caught in their regular fishing operations under penalty of revocation of all shellfish permits. Later a State law was enacted to that effect.

Late in 1933 the CWA, a Federal relief agency, was induced to accept marine fisheries projects, and during the years 1934, 1935 and 1936 an estimated amount of 95,310 bushels of starfish were collected under CWA, ERA and WPA. The state and towns acted as co-sponsors and contributed certain amounts to the program. While very appreciative of this assistance, it should be remembered that the principal objective of this Federal work was relief to the unemployed, and the main effort therefore was wages and not results. Consequently this contribution should never be considered from the standpoint of practical efficiency. In Federal relief work the reimbursement was on a day basis, and the actual quantity of starfish collected was often estimated by relief foremen, the accuracy varying with their

personal ability. The State, as sponsor for the project, endeavored to standardize estimation.

Previous methods were not adequate for such a widespread menace. Cotton mops, such as were in general use by commercial oyster fishermen, could not be used, because the boats of local fishermen were not equipped with them and they were not large enough to handle them, nor could sufficient funds have been obtained to supply them. Furthermore, it was decided that this method was not efficient enough to rapidly and economically reduce the tremendous number of stars. Copper sulphate, an emergency measure advocated by the U. S. Bureau of Fisheries, could not be used, because of its toxic effect upon the food supply of the shellfish as well as for other reasons. The use of lime had not at that time been fully demonstrated, nor is its use even now advocated by this Division for such extensive use. It was therefore decided to use the small scallop dredges, with which most fishermen's boats were equipped. The use of these was supervised and the areas in which they operated were restricted in order to minimize possible damage to seed or adult shellfish.

In state and town work wherever possible (probably in 90% of the work) the fishermen were paid on the bushel basis, the amount of collection being checked daily by State and local fishery officers. At the commencement of the work and until the concentrations were considerably reduced, the fishermen were paid on the basis of the number of bushels collected. Later an hourly wage was paid for work which was strictly supervised.

By 1936 the abundance of starfish had become so reduced as to necessitate a different handling of the problem. No longer did we organize groups of boats and give them a general area in which to collect the starfish, but we actually located the beds of starfish and fished that area with a few selected fishermen under our direct supervision until the starfish were reduced to a nonpaying quantity. Our technique naturally had improved so that even an area in which the stars were scattered could be worked successfully; consequently the per-bushel price was kept low. When the fishermen were paid by the hour, our supervision included such details as the kind of dredge and the number of them to be used, length of dredge line in that area and the boat speed. Collections by State and towns were largely but not exclusively made in the months of April through November.

At the outset we were handicapped in our work by a woeful lack of

knowledge as to the migratory habits of starfish. In fact in July, 1932, when the first appropriation became available, the fishermen reported that the starfish had disappeared. Believing that there was no chance of such luck, I personally made a survey of the locality, and after a few days of systematic work located an area of great abundance in the vicinity of Cleveland's ledge in Buzzards Bay, about four square miles in area with an average depth of twenty feet. From this area, in spite of considerable stormy weather, 4,000 bushels of stars were taken in three weeks. It was interesting to note that more than 10 per cent of the starfish collected in this area were still full of spawn, although they were taken in the month of August, and July 1 had been considered as the end of the usual spawning period. In the cooler weather the remnants of these stars and others from smaller areas of concentration moved back into the shoaler waters. The knowledge of this seasonal migration was taken full advantage of in later work.

In the five years of concentrated work, 1932-36, 256,714 bushels were collected, representing more than 3,800 tons, and, at an average of 300 per bushel, more than 77,000,000 individuals. By the end of 1936 the concentrations of starfish had been greatly reduced over the entire area, and the work in 1936 consisted mainly of large-scale mopping-up operations. In areas where at the beginning of the work individual boats had brought in as many as 197 bushels in one day and averaged 100 bushels per day, these same areas yielded from 16 to 20 bushels per day.

The public scallop and quahaug fishery has been on the increase throughout the menaced area in spite of more intensified fishing.

Among other interesting things observed in this campaign was a tendency of the starfish to concentrate in certain definite spots in each area. The reasons for this concentration are very obscure and certainly not directly connected with the abundance of food. This is particularly evidenced by the migration of stars into a newly dredged area. In fact it became a common practice to thoroughly dredge a certain small area and then leave it for two or three weeks. Upon returning it would usually be found that a new concentration of stars had moved in from surrounding areas, even though at times the stars had left beds of seed scallops to do so.

It is not expected that the work done in the suppression of starfish has eliminated them as a menace in the affected areas, but it does

demonstrate that something can be done about it. Starfish will continue to be a menace to the shell fisheries and from time to time will be present in great concentrations; but the experience which has been obtained in the suppression of them has left a certain definite assurance that, with careful observation as to the abundance of stars in our shellfish areas, serious trouble can be anticipated and prevented. Since 1936, wherever a concentration of stars was observed in a certain area and we were notified of the fact, or if it was observed by ourselves, we were able to remove the menace rather quickly and inexpensively.

A most important contribution of this work to the Marine Fisheries was that it aroused local interest in protective conservation measures and induced a spirit of cooperation between the towns and the State, which is always a healthy condition for a conservation program. Eventually in Massachusetts this work in the suppression of starfish developed into a permanent policy of shellfish assistance supported by an annual, though modest, appropriation.

TABLE I. STARFISH SUPPRESSION BY MARINE FISHERIES MASSACHUSETTS

	1932	1933	1934	1935	1936
	<i>Fiscal</i>	<i>Fiscal</i>	<i>Fiscal</i>	<i>Fiscal</i>	<i>Fiscal</i>
	<i>Year</i>	<i>Year</i>	<i>Year</i>	<i>Year</i>	<i>Year</i>
Total Bushels Collected	56,120	53,656	63,567	30,250	53,121
Collected by State	43,127	39,331	10,238	5,250 ¹	35,121 ¹
Collected by Towns	12,993	14,325	1,016		
Collected by Federal Gov't.	none	none	52,310	25,000 (Est.)	18,000 (Est.)
Paid by State	\$8,711	\$14,937	\$4,924	\$1,472	\$13,991
Aver. cost to State	20.0c	37.9c	48.0c		
Paid by Towns	\$2,903	\$6,059	\$8.07	\$741	\$9,340
Aver. cost to Towns	22.0c	42.3c	79.4c		
Total cost to State and Towns	\$11,614	\$20,996	\$5,731	\$2,213	\$23,331
Aver. cost to State and Towns	20.6c	39.1c	50.9c	42.1c	52.9c
Federal Costs	none	none	OWA ²	ERA ²	WPA ²

¹ During these years all starfish projects, except those by the Federal Government, were operated jointly by State and Towns. The only possible separation was in expenditures which were in proportion agreed upon.

² Federal costs unknown since total expenditures included many items, allowances and top supervision only remotely connected with collection costs. The major federal effort was directed toward securing wages for the unemployed regardless of the value of their contribution to the project.

TABLE II. AMOUNT OF MASSACHUSETTS STATE EXPENDITURES (IN DOLLARS) CHARGED TO STARFISH, 1932-1942

Area	Township	1932 ¹	1933 ¹	1934	1935	1936	1937	1938	1939	1940	1941	1942	Total
Bourne	Bourne	4233		554	0	0	0	0	0	6	0	0	4793
	Wareham	7414		1078	42	1736	680	0	0	0	212	424	11586
	Marion	3090		970	102	1541	116	0	0	420	0	0	6239
	Mattapoisett	4269		519	90	1634	55	0	0	237	0	0	6804
	Fairhaven	1047		555	136	899	0	0	0	553	0	0	3190
	New Bedford	0	701	45	688	2257	0	0	0	0	0	0	3691
	Dartmouth	0	1021	49	0	863	0	0	68	234	178	0	2413
Barnstable	Falmouth ²	0	0	434	551	145	0	0	0	0	0	0	1130
	Total	8711	+ 13064	- 4204	1609	9075	851	0	68	1450	390	424	39846
Chilmark	Chilmark	0	0	0	0	776	260	0	0	0	0	0	1036
	Tisbury ³	0	233	64	0	240	193	1612	440	382	549	412	4125
	Oak Bluffs ³	0	3	0	0	373	154	1048	342	911	339	628	3798
	Edgartown	0	1430	640	0	1812	380	1156	633	615	0	0	6666
	Barnstable	0	0	0	0	10	0	900	942	0	0	0	1852
	Nantucket	0	0	0	0	1421	443	0	0	0	0	0	1864
	Swansea	0	208	17	0	224	0	714	0	0	0	0	1163
Grand Total		\$8711	+ \$14938	- \$4925	\$1609	\$13931	\$2281	\$5430	\$2425	\$3358	\$1278	\$1464	\$60350

¹ Separate returns for 1932 and 1933 not available for certain towns. Total expenditure listed for the Buzzards Bay region in 1932 does not include Fairhaven, disbursements for which since August, 1932 are included under the 1933 total.

² Starfish collected on both Buzzards Bay and Vineyard Sound shores.

³ Although amounts spent in these towns are charged to starfish, the work consisted largely of dredging and removing accumulated trash which contained quantities of a small starfish species not determined, seldom over 2 inches in diameter.

GENERAL DISCUSSION OF PROBLEMS INVOLVED IN STARFISH UTILIZATION

BY MARTIN D. BURKENROAD

Bingham Oceanographic Laboratory, Yale University

To evaluate the possibility of utilization of starfish requires an examination of the balance existing between the following inter-dependent factors:

1. The value of and demand for starfish products.
2. The costs of preparing and marketing the products.
3. The quantities of raw material available and the costs of its production and delivery.

The preceding sections of the present volume provide much valuable information upon these factors. However, they are insufficient by themselves to enable any definite conclusions to be drawn as to the possibilities of establishing a starfish industry in southern New England under foreseeable conditions. In order to comply with Dr. Merriman's invitation to prepare a concluding section, it has been necessary to make a variety of further enquiries. Extensive and generous aid in this work has been granted me from many sources; and I should like here, in anticipation of detailed acknowledgment which will appear in a forthcoming report upon the natural history of the starfish, to express my sense of gratitude and deep obligation to all who have helped.

FACTOR 1. VALUE OF AND DEMAND FOR STARFISH PRODUCTS

The first six papers of the present publication serve to demonstrate, in a more critical way than has been attempted heretofore, that starfish meal is of value as a foodstuff for domestic animals. The general result obtained by experimental feeding of chicks upon diets containing a proportion of dried and ground starfish is that, in quantity less than six per cent of the ration, starfish is about equivalent weight for weight as a growth-promoter to such standard protein supplements as sardine meal. In view of the relatively low protein content of starfish

meal this is a surprising result, which appears to be worth further investigation. In addition, the non-protein content of starfish meal apparently replaces the shell or limestone meal otherwise required by poultry as a source of calcium. Spectrographic and microbiological assays by Hutchinson *et al.*, in addition to defining the quantities of valuable substances contained in starfish, provide assurance that there will be no unexpected after-effects of feeding as a result of detrimental concentrations of the trace-elements fluorine and strontium. In two further papers of the present publication (those of Gibbs and of Nelson), incidental consideration is given to the use of starfish as fertilizer for crops. Although the favorable conclusions presented are not based upon controlled experiment, the information represents an advance over that heretofore available, in providing assurance that no adverse effects accompany the application of starfish to soils.

The maximal price obtainable at present for starfish meal would apparently be set by an O. P. A. ceiling upon materials intended for animal feeding. This ceiling is based upon protein content. Because of its relatively low protein content, starfish meal would not bring more than \$42 per ton, in sacks, f. o. b. shipping point. The potential demand at this price under present conditions is apparently very large. Starfish processed like menhaden scrap is reported to have brought a price of about \$43 a ton as feed or fertilizer in Virginia in 1937-8.

Should a weight-for-weight equivalence of starfish meal to fish meal as a growth promoter for young chicks be confirmed, a higher price for starfish meal than its gross protein content would justify might be established upon an open market. It is also possible that starfish might prove upon enquiry to be capable of supplying products of greater value than animal feed or fertilizer; for example, the gonads might conceivably serve as human food; or derivatives of special medical or industrial use might be discovered. However, such possible developments are beyond the range of the present evaluation.

The value of starfish captured upon the coast of southern New England is peculiar in having a negative as well as a positive aspect. In addition to its potential usefulness as a raw material, a starfish removed from an oyster-bed has a definite value to the oyster grower, based upon the amount of damage which would otherwise have been caused by it. This negative value is best considered under Factor 3 (Costs of Production).

FACTOR 2. COSTS OF PREPARING AND MARKETING THE PRODUCTS

We are informed by Mr. John Ryan, President of Dehydrating Process Company, Boston, that starfish offers no special dehydration problems. It was successfully handled by his company (in preparing the meal used by Morse, Griffiths and Parkhurst, as reported in the present volume) by the same means as for fillet trimmings from non-oily fish (cod and haddock), as follows: the wet weight of batches of material is first reduced by 50 per cent in rotary vacuum dryers, at a 26 inch vacuum with 45 pounds of steam pressure on the dryers. In the second stage, the cooked, semidried scrap is put through a Louisville steam tube dryer and reduced to seven to eight per cent moisture. It is then ground in a hammer mill. The yield of dry meal to raw starfish was 22.5 per cent, slightly lower than for cod and haddock.

The minimal present cost of processing fish meal, by methods such as the above, capable of turning out premium meals, and in a plant producing about 5,000 tons of meal per year, is believed by Mr. Ryan to amount to at least \$42.00 per ton exclusive of the costs of raw material. The distribution of this cost would be roughly as follows (\$ per ton of meal); Labor, 14.00; Power, 2.00; Heat, 5.50; Sacks, 2.50; Indirect (Building-rental, Office and other supplies, Maintenance, Taxes, Insurance, etc.), 6.00; Transportation and sales, 1.00; Administration, Bank charges, etc., 8.00; Depreciation, 3.00; Total \$42.00. In the case of fish meals with a protein content of 50 per cent to 75 per cent, selling at a ceiling of about \$1.20 per per cent of protein per ton, the above costs would by no means be prohibitive, and are in fact considerably lower than are now attained in practice.

According to Mr. Ryan, fish meal plants are normally designed with a potential capacity for production more than twice that which they actually achieve; this is because unavoidable irregularities in the delivery of raw material require that the plant be able to handle peak loads when they are available. Actual production at Boston and Gloucester is estimated to be on the order of only 40 per cent of plant capacity, because of seasonal and other fluctuations in the supply of fish. A plant able to handle less than five tons of raw fish per hour is thus not regarded as economical. Under the conditions with which Mr. Ryan is authoritatively familiar, "At \$5.00 per ton at the dock (for non-oily fish wastes, amounting to a raw-material cost of about \$22 per ton of meal), a production of 3,000 to 5,000 tons of meal (per year,

requiring between 13 and 22 thousand tons of fish) would warrant putting in the equipment to process, if you could be assured of getting tonnage year after year. Equipment to process this amount, including Boiler Plant, would be 125 to 150,000 dollars, which would not include building."

Mr. Ryan's remarks are of course not intended as a conclusive statement of the costs of processing starfish, inasmuch as differences between the conditions of operation with fillet trimmings and with starfish (as, for example, in the regularity of delivery of the raw material) might be great. For comparison with the above costs, we are informed by an oyster grower of Mobjack, Virginia, that during the winter of 1937 he was able to sell for a price of about \$43 per ton the product of an average daily catch of raw starfish amounting to about 18 tons, processed with steam cooking and steam drying equipment. Since his raw material costs are estimated to have been between \$2.50 and \$4 per ton wet, or between \$11 and \$17 per ton of finished product, his processing costs may be presumed to have been less than \$32.00 per ton, unless the enterprise was operating at a continuous and obvious loss. This enterprise was discontinued after about a year, upon disappearance of the masses of starfish which had, by their sudden and unique development in Chesapeake Bay, stimulated the initiation of the industry. It has not been possible to determine whether the enterprise could have returned a net profit had the peak level of the local population of starfish been maintained.

It seems possible to say one thing rather definitely about the processing of starfish for feed or fertilizer, namely, that the basic manufacturing costs would apparently be about the same as for other raw materials. In consequence, whatever industrial mode is considered, from one-man sun-drying on up, starfish would have to compete on an equal footing with other materials as regards processing costs. If, therefore, the market value of the finished starfish meal is lower than that of other comparable products, investment in a starfish industry would be unattractive unless the unfavorable differential in the value of the finished product could be balanced by a favorable differential in regard to the supply of raw material.

The cost of non-oily fish wastes to the processor amounts to at least \$20 per ton of finished product. Oily fish or wastes generally cost more as raw material (for example, menhaden is obtained not as a by-product but from a primary fishery), but the value of the oil is

such that the protein residue may in fact be regarded as a by-product just as much as the non-oily wastes from ground-fish filleting houses. As far as can be learned, the difference in market value between starfish meal and fish meals would be more than \$20 per ton at present, which is about the same as the cost of raw non-oily fish wastes sufficient to make a ton of meal. Consequently, even if raw starfish were cost-free, it might not pay to process them.

To summarize, it appears that the manufacture of animal feed or fertilizer from starfish would be unprofitable under present conditions, even if the conditions of supply of raw material were exceptionally favorable (which, as will be shown in the next section, is not the case).

FACTOR 3. QUANTITIES OF RAW MATERIAL AVAILABLE AND COSTS OF PRODUCTION AND DELIVERY

The sections by Barnes, Gibbs, Nelson and Sweet in the present publication provide information concerning the existent New England fishery for starfish. This fishery is based upon the need to combat this animal as a destructive pest. Starfish caught for this reason, chiefly as a by-product of the oyster industry, might be a possible source of low-cost supply for a starfish processing industry. Put in another way, funds expended by private oyster growers and by public authorities for the protection of economic mollusks from starfish represent a possible contribution to the costs of supplying starfish for processing.

However, it does not appear practicable to found a starfish industry upon the by-product catch alone, quite apart from the question of costs of processing. To judge from available information, the entire catch of starfish in southern New England, from all sources and in years when starfish have been most abundant, has probably never approached 20,000 tons; in fact, Sweet estimates the catch in the whole of Connecticut in 1942 (a year of abundant starfish) to have been no more than about 1,200 tons, capable of producing no more than about 275 tons of meal. Further, this existent production of starfish is scattered along a coast extending from Cape Cod to New York; and in order to utilize it, the scattered catches would have to be collected and delivered at almost daily intervals to a limited number of processing plants. The cost of such delivery would be considerable. Finally, a third difficulty in utilizing the by-product catch of starfish is that the gear most commonly employed for destruction of the pest is

the mop-dredge, which can be used for the selective removal of starfish from beds already planted with oysters. The starfish, entangled in and clinging to the mops, are usually killed by immersion of the gear in hot water, after which the mops are cleared for further fishing by being dragged overside. The expense of disentangling the starfish upon deck is (as Sweet points out above) appreciable; and in consequence a large, or the major, part of the existent catch of starfish probably could not be landed except for a price sufficient to cover the added costs of retaining them.

In view of the above difficulties, it seems unlikely that under present conditions any significant amount of starfish could be supplied at low cost to the processor as a by-product of the oyster industry.

The cost of production of starfish by a fishery established primarily for this purpose may now be considered. It will be seen from the remarks of Barnes that the lowest bounty ever paid for starfish by the State of Massachusetts was about \$10 per ton, and that the yearly average price ranged from \$14 per ton in 1932 to \$35 per ton in 1938. The bounty paid in Rhode Island in 1941 amounted to about \$15 per ton, according to the account of Gibbs, although the eager response of the fishermen (resulting in a catch of 600 tons in one month) suggests that this price may possibly have been above the minimum required. In contrast to these prohibitive New England prices, we are informed by the Virginia processor referred to above that his two-dredge oyster boat, costing between \$45 and \$60 a day to operate, made an average daily catch of 500 bushels (estimated to weigh about 18 tons) or more of starfish in the Chesapeake during the winter of 1937. The cost of producing starfish in Virginia, therefore, evidently amounted to between \$2.50 and \$4 per ton.

The differences between the costs of production of starfish in New England and in the Chesapeake, and between those in Buzzards Bay in 1932 and in 1936, clearly relate, in major part at least, to differences in the abundance of starfish at these times and places. For example, against the average of 18 tons per boat per day in the Chesapeake in 1937, the highest catch in Buzzards Bay between 1932 and 1937 is reported to have been about $2\frac{1}{2}$ tons (a difference far too great to be referred to differences in effectiveness of equipment alone). On the other hand, it seems certain that in 1942-43, much larger catches per boat per day could have been made in New England (where starfish

became excessively abundant at this time) than in the Chesapeake (where starfish had become scarce¹).

That great fluctuations in the amount of trouble with starfish do occur has in fact been recognized for a century by New England oyster growers. Therefore, in order to determine the potential costs of production of starfish, it has been necessary to enquire into the nature and extent of these fluctuations. As a preliminary report on the results of this enquiry is now in press (Burkenroad, 1946, *Science*) and a full report is in preparation, only a brief summary need be given here. Statistics upon the abundance or catch of starfish are lacking, save for a thirty-year record of the annual catch upon its oyster beds by an oyster company in Narragansett Bay, and a similar seven-year record by a company in Connecticut. These records show great changes from year to year (for example, the Narragansett Bay Company caught less than five tons of starfish in 1922, against 650 tons in 1929); but these differences might conceivably refer to changes in fishing effort, or to fluctuations of a merely local sort, balanced by converse changes on neighboring oyster grounds.

In an attempt to determine whether these available limited quantitative records might be representative of general conditions, and whether the changes in magnitude of these recorded catches might correspond with changes in the abundance of the general population of starfish, a method of estimating the relative amounts of trouble with starfish over a long period has been devised. Systematic search of the reports of public commissions, newspapers and trade journals, etc., covering the last hundred years, has yielded a total of 185 items bearing on the abundance of starfish on the oyster beds at various times and in various parts of southern New England. These various

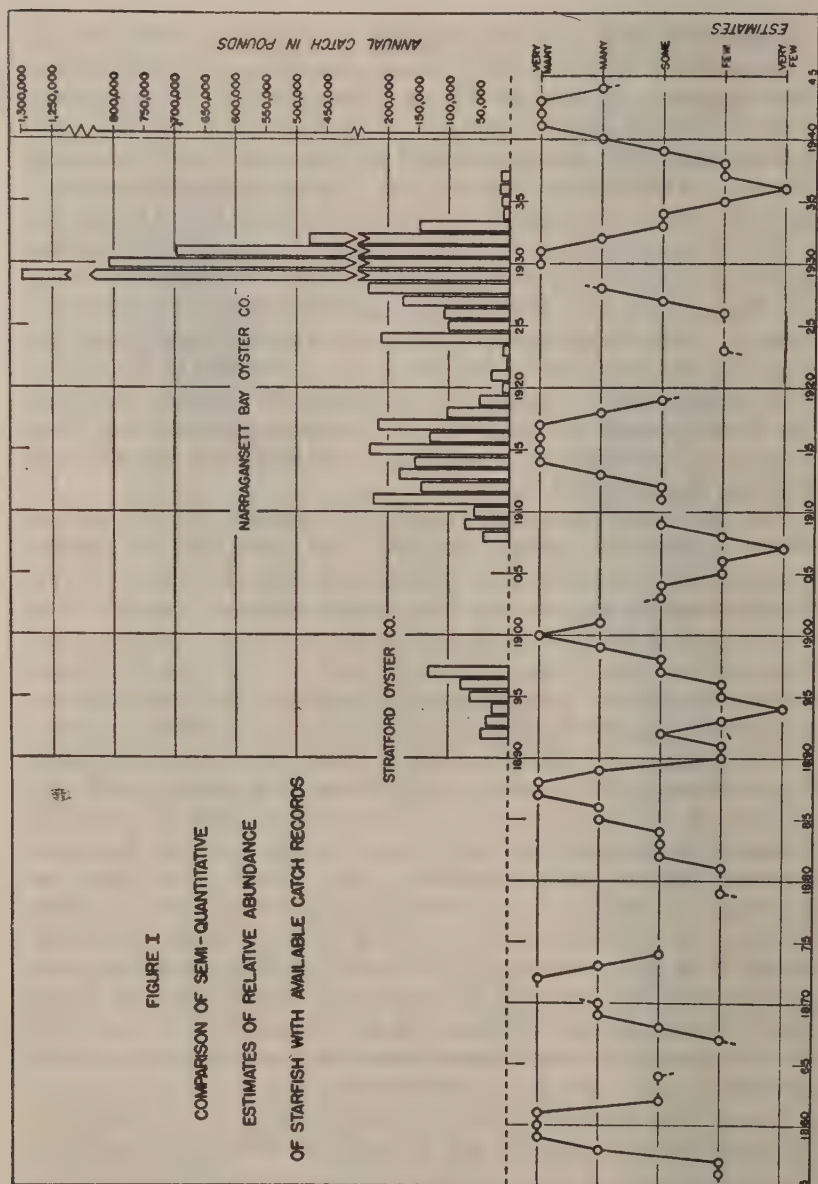
¹ According to personal communications from several sources, confirmed by Mr. R. L. Miles, of J. H. Miles and Co., Norfolk, Va. (Feb., 1945, *in litt.*): "I have been familiar with the oyster business in Maryland and Virginia for sixty years. We never heard of starfish being in Chesapeake Bay until about ten years ago when they came in large quantities in the fall of the year [1936?] . . . twenty-five or thirty miles up the Bay from the Capes was as far as they went. . . They were quite thick here for two years . . . With the exception of those two years [when slight damage to oysters occurred] they have never bothered us very much . . . For the last two years we have not been bothered at all . . . some of the crab boat captains . . . told me [that] for a few years prior to [starfish] . . . coming in Chesapeake Bay so thick, they would catch a few at [or just outside the] mouth of Cape Henry . . . but they [starfish] never came in [to the Bay proper] as far as we know until they did as stated above."

statements have been graded according to whether they seem to indicate that there were very many, many, some, few or very few starfish, and compared. It is found that, in those numerous instances where reports from all parts of southern New England during the same period are available, the relative local abundance of starfish was everywhere much the same at the given time. Therefore, the estimates have been summarized, and plotted as shown in the lower half of Figure I.

The upper half of Figure I is based on the reports of actual catches by the two oyster companies from which adequate records have been obtained. It shows a nearly perfect correspondence as regards the times of peaks and troughs with the indications obtained from the semiquantitative estimates plotted in the lower half of the figure. This correspondence appears sufficient to support the conclusion that the fluctuations in the available catch records are correlated with changes in abundance of starfish on oyster-beds over the whole of southern New England.

The next question to be considered is whether the changes in abundance of starfish upon oyster-beds might result, not from changes in abundance of the general population, but from shifts in the distribution of starfish such as might be caused, for example, by a depletion of wild food resources such as mussels or coot-clams. Enquiry into this question shows that, although the annual catches of the Narragansett Bay Oyster Company cannot be regarded as directly proportional to the magnitude of the general population of starfish, a correlation does exist. For example, analysis of the information supplied by Barnes (present volume) shows that the density of starfish population in Buzzards Bay declined much as did the catches of the Narragansett Company during the same period; and further, that this decline in Buzzards Bay can hardly have been an effect merely of the fishery for starfish. Comparison of the results of the general population survey in Long Island Sound made in 1935-6 by Galtsoff and Loosanoff (Bull. U. S. Bur. Fish. 31: 75-132, 1939) with informal reports of later surveys by Loosanoff and other information, likewise shows that the great increase in trouble with starfish from 1941 on must have resulted from an increase in magnitude of the general population, and not merely from a change in its distribution.

It is the general practice of the oyster grower (and we are specifically informed that this practice was followed by the Narragansett Bay Oyster Company) to increase the intensity of his efforts at starfish



control with increase in the abundance of starfish. In consequence, the catches of the Narragansett Company may be assumed to have varied from year to year not only because of changes in the abundance of starfish but also because of variations in the fishing effort. Making certain reasonable assumptions as to what this change in fishing effort is likely to have been, and correcting the records by this factor, it seems probable that the catch per unit of effort in an average year of peak abundance was of an order 10 to 20 times that in an average trough year.

It will be seen from Figure I that the changes in abundance of starfish have been of a regular sort repeated at intervals of fourteen years. Cyclical changes in abundance, of the great magnitude indicated, would obviously have an enormous effect upon the costs of a fishery. The period in which a bounty of \$14 per ton was sufficient to create a fishery primarily for starfish in Buzzards Bay (1932) came about three years after a peak of the cycle; and the period in which a bounty of \$15 per ton was highly effective in Narragansett Bay (1941) came a year or two before the time of the next peak of the cycle. It thus seems possible that during the actual peak years themselves the costs of fishing starfish in southern New England might conceivably fall as low as those in Chesapeake Bay in 1937.

To examine this possibility, an analysis has been made of data on the population of starfish in New England in 1935-6 and in the Chesapeake in 1937-8, supplied by Galtsoff and Loosanoff (1939, *op. cit.*). The details of this analysis need not be given here; the results are summarized in Table I. When the estimated density of population per acre in New England in the trough year 1935-6 is corrected by a factor representing the difference between 1935-6 and an average peak year, we arrive at a value of about one-half ton per acre for the average peak density of population on the half-million acres within the common range of *Asterias forbesi* in southern New England. This density is about the same as that estimated for the Chesapeake in 1937-8; and although the estimates rest upon inadequate data and have been reached by way of a network of hypothesis and assumption, it is probably safe to conclude that, for perhaps two years in every fourteen, starfish could profitably be fished in New England at a price as low as \$3 to \$5 per ton. At other times, however, the cost of production of starfish would undoubtedly rise at least as high as \$30 per ton, and the long term average would hardly be less than \$15 per ton. At this

average price, it would take about \$64 worth of raw starfish to make one ton of starfish meal.

A processing industry existing upon other sources of raw material than starfish for eleven or twelve years out of every fourteen, but with equipment to take advantage of the great abundance of starfish available when the peak of the cycle arrives, might conceivably be profitable if the value of the finished starfish product and the costs of processing were in favorable relationship. However, the disparity between the amounts of starfish potentially available during peaks and the amounts of raw materials other than starfish potentially available year after year in the regions where starfish periodically become abundant, is very great, and in consequence, a permanent plant would have to be of highly uneconomic design in order to be able to take advantage of the starfish peaks. For example, even if the Connecticut trawl-fishery could be so organized as to deliver to a processor trash fish and filletting wastes equal in quantity to the tonnage of edible fish annually caught by it, the processing plant would receive only about 6,000 tons of fish per year, equivalent to about 1,400 tons of meal. Thus, even if a Connecticut processing plant were designed with a maximal capacity four times its normal turnover, it would be able to handle no more than 24,000 tons of starfish per year during starfish peaks, so that its *average* production of starfish meal would probably amount to considerably less than 1,000 tons per year.

The only obvious means of coping with the inequalities of the supply of starfish would therefore seem to be a mobile processing plant (comparable with the floating plant currently used in the manufacture of herring meal and oil) able to range from place to place to take advantage of seasonal and periodic gluts of other products as well as of starfish. Such an arrangement would still face the difficulty that, in the case of starfish, periodic availability not only of the processing plant but of the fishing fleet to supply it, would be required. It is unlikely that even under the most favorable circumstances a production of raw material equivalent to 1,000 tons of starfish meal per year per fishing vessel could be obtained, so that a fleet of more than five vessels equivalent to the average oyster dredger would have to be available during starfish peaks to support a processing unit of the dimensions regarded by Mr. Ryan (see under Factor 2 above) as economical. Practicable arrangements for the temporary availability of such a starfishing fleet are somewhat difficult to envisage.

It therefore appears that the factor of supply of raw material is decidedly unfavorable to the utilization of starfish as a source of animal feed, at least as far as immediately foreseeable conditions are concerned.

One remote possibility of reducing the costs of production of starfish remains to be considered. The oyster growers of Connecticut alone are conservatively estimated to spend an average of at least \$100,000 per year for the control of starfish. This sum amounts to an expenditure of at least \$100 per ton of starfish captured, even in years of peak abundance. Such a cost of production is very much higher than would be attainable if the aim were to catch as many starfish as possible instead of to keep the oyster-beds clear. The question may therefore be raised as to whether or not the expenditure of \$100,000 per year to remove as much of the general population of starfish as possible might reduce the damage inflicted by the pest to lower proportions than does the present method of control.

It has been maintained (Galtsoff and Loosanoff, 1939, *op. cit.*) that movements of starfish from place to place on the bottom are of an extremely limited sort, and that the supposed "raids" and "invasions" of oyster beds result merely from growth *in situ* of young starfish settled upon these same beds as larvae. However, re-analysis of the distributional data offered in support of this view does not seem favorable to it. Furthermore, data obtained from reliable commercial sources affords convincing evidence that mass movements of adult starfish do occur. The evidence against mass movement yielded by Loosanoff's ingenious marking experiments in 1935-1936 may reasonably be interpreted as meaning that, during trough years or at other times when food is locally abundant, no stimulus to movement exists. If extensive movements do occur at times of abundance of starfish, it seems possible that the decimation of concentrations of starfish which lie within range of oyster bottoms might greatly reduce the rate of invasion (although use of the mop-dredge to remove starfish which had settled as larvae upon the beds themselves would still be a necessary accessory procedure).

It appears extremely unlikely that fishing operations of practicable magnitude could so reduce the level of the population of starfish during periods of abundance as to make any appreciable difference in the magnitude of the set of young starfish.² The same is not necessarily

² Without attempting a detailed criticism of current views in the present essay, it

true, however, during trough periods, when, as indicated in Table I, the total population of starfish in Long Island Sound may amount to no more than 30,000 tons. The removal of, say, 10,000 tons of starfish at such a time might conceivably so reduce the set as to interfere with the development of the cycle. Such removal might thus be profitable to the oysterman, although exceedingly costly in terms of price per ton. However, it seems equally possible (for reasons which are too complex to be appropriate for presentation here) that reduction of the spawning stock by even half or more might make little difference as regards the production of a new generation. It is also possible that the balance of life in Long Island Sound is so adjusted that serious interference with the starfish stock by human agency might, if attainable, result in the development of populations of oyster-drills, mussels, *Crepidula*, etc. of such proportions as to constitute a great menace to the oystermen.³

Even should research demonstrate that the support of a fishery intended to capture as many starfish as possible would be profitable to the oyster grower, such a fishery might not be of much assistance in permitting the processing of the catch. The interests of the processor and the oyster grower are in fact opposed; the former wants a steady supply of raw material at a low cost; whereas to the latter, in the words of Gibbs "The possibility of exterminating the starfish will be our last concern." The price which a processor would be able to offer for starfish would not be an appreciable contribution to the costs of fishing during years of scarcity; while the quantity of starfish which could be annually handled by a processor equipped with reference to the regularly available supply would be insignificant in comparison with the amount which the oyster grower would have to dispose of in peak starfish periods. In consequence, little stimulus toward organization of the fishery for delivery of starfish to the processor would exist.

may be stated that the hypothesis that larval starfish settle in the same locality where spawned does not seem to be supported by any critical evidence, and may be regarded as mere analogy from the unproven hypothesis that larval oysters in Connecticut do not move far from the spawning grounds.

³ Some tentative calculations concerning the energy-budget of Long Island Sound (to be presented elsewhere), based upon Riley's production figures and Petersen's and Lindeman's trophic-dynamic equivalents, do indeed suggest that the starfish may serve as a sort of biological governor, in the absence of which the balance of the ecosystem might shift in unforeseen directions.

TABLE I. ESTIMATED STOCKS OF *Asterias forbesi* (OF DIAMETER MORE THAN 2 CM.) IN SOUTHERN NEW ENGLAND IN 1935-6, COMPARED WITH ESTIMATED STOCKS AT PEAKS OF ABUNDANCE IN SOUTHERN NEW ENGLAND AND IN CHESAPEAKE BAY.¹

Region	Area in Acres	No. of Samples	No. of Starfish Dredged	Average stock in 1935-6				Average stock during peaks of abundance			
				No. per Sq. Meter	Gms. per Sq. Meter	Tons per Acre	Total Stock in Tons	No. per Sq. Meter ²	Gms. per Sq. Meter	Tons per Acre	Total Stock in Tons
<i>Buzzards Bay</i>											
Total:	190,000	256	1,150	0.13	1.5	0.007	1,250	—	27	0.12	22,500
Bottoms < 41 feet deep ⁴	100,000	188	1,121	0.22	2.5	0.011	1,100	—	45	0.20	20,000
<i>Long Island Sound</i>											
Total:	1,099,000	323	5,037	0.44	5.6	0.024	27,000	—	100	0.44	486,000
Bottoms < 40 feet deep	333,000	153	4,388	1.07	13.7	0.060	20,000	—	247	1.08	360,000
Connecticut, total populated area	191,000	88	780	0.32	4.1	0.018	3,500	—	74	0.32	63,000
Milford (Bottoms < 40 feet deep)	13,000	260	4,818	0.68	8.7	0.039	500	—	157	0.70	9,000
<i>Chesapeake</i>											
Total populated area	279,000	24	771 ⁶	—	—	—	—	2.64	120	0.53	148,000

¹ Sampling surveys made by Galtsoff and Loosanoff (Bull. U. S. Bur. Fish. 31: 75-132, 1939). Narragansett Bay omitted for lack of evaluable data. Constants employed in present calculations are as follows: Acreage per sampling-haul, .0405. Difference between number of starfish taken by sampling-dredge and number present on the area sampled, six times. Average weight of starfish: Buzzards Bay, .025 lb.; Long Island Sound, .028 lb.; Chesapeake, .10 lb. Difference in weight of starfish per unit area in 1935-6 and in average peak periods of cycle of abundance in southern New England, 18 times.

² Average number of starfish per square meter during peaks of abundance in New England not estimated, since average size during troughs may be less than that during peaks. The maximal weight indicated, 247 g. per average m² of bottoms at a depth of less than 40 feet in Long Island Sound, would be equivalent to a number per m² of about five large (diameter, 12-15 cm.) starfish.

³ Total stocks estimated by adding probable percentage of population in deep water to estimated shallow water stock, rather than directly from total acreage multiplied by mean weight per acre of all samples, because of asymmetrical distribution of sampling-hauls.

⁴ Several alternative values are available for number of hauls and total catch in shallow water, the records of the sampling survey being ambiguous.

⁵ Although the number of starfish actually captured was 771, several of the sampling hauls were not of standard type, and the estimates of the stock are therefore based on a corrected total catch of 1,717 starfish.

CONCLUSIONS

Regular large-scale utilization of starfish as protein feed or fertilizer seems to be entirely impracticable under present conditions. However, it is conceivable that future developments of an unpredictable nature, dependent upon researches not yet completed or even begun, might cause this sometimes abundant pest to become a potentially valuable resource. Information included in the present publication may be expected to be contributory to any such development.

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STUDIES ON THE MARINE RESOURCES OF
SOUTHERN NEW ENGLAND

IV. THE BIOLOGY AND ECONOMIC IMPORTANCE
OF THE OCEAN POUT, *MACROZOARCES*
AMERICANUS (BLOCH AND SCHNEIDER)

By

YNGVE H. OLSEN AND DANIEL MERRIMAN

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Bingham Oceanographic Laboratory

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ABSTRACT

Ocean pout are abundant from the Gulf of St. Lawrence to Delaware and average 16-28 inches (0.7-4.0 lb.). In 1943 they were introduced to the market in fillet form, and over 10,000,000 pounds were landed in two years, the majority being taken by trawlers off southern New England in 15-25 fathoms. The major objectives of this work were: 1. to collect data on the life history, availability and catch statistics in order to provide a basis for the rational utilization of the stock; 2. to gather information on the parasites, their effect on the marketability of fillets, and the incidence of infections.

Economic considerations. Spectacular growth of the fishery is described, and its seasonal and geographical particulars are presented. The fishery is capable of producing far more than it did in 1943-1944. The catch of ocean pout, heretofore discarded, was significant because of the trend toward greater use of "trash" species, which implies a closer approach to optimal utilization of available marine resources. More extensive use of such resources provides wider assortment of fisheries products

and relieves the drain on primary stocks so that the economic security of members of the fishing industry is less hazardous. Attempts by the Office of Price Administration to control the ocean pout culminated in a 3-cent ceiling which reduced the landings to a relatively low level. An embargo in New York by public health officials as a result of its parasitization further reduced the landings. Judgment on the ocean pout fishery, which has much to recommend it if the parasitological and marketing problems can be overcome, was precipitous and inadequately considered. The present paper should provide a fairer basis of evaluation.

Preliminary discussion. Literature is reviewed; common names, range in latitude, depth and bottom habitat are discussed. Ocean pout are abundant on southern New England fishing grounds during winter and spring, but are absent in summer and fall. There is no evidence of coastwise migrations. The major part of the population probably remains in the same general region in which it is taken in winter and spring, but moves into rocky areas where capture by trawl nets is fortuitous from June to December. Size and length-weight data are presented. Vitamin A analyses of livers from southern New England and the Bay of Fundy gave values of 607 and 16,500; possible causes for these differences are mentioned.

Classification, etc. Nomenclature, generic and specific characters and detailed descriptions are presented. Heterauxesis is demonstrated in the growth of different parts of the body, and the osteology of the caudal fin is described.

Life history. By contrast to the European *Zoarces*, American ocean pout are oviparous. The number of eggs varies from 1300 in intermediate sized fish to 4200 in large individuals. The percentage of the weight of the females occupied by the ovary at any particular date tends to increase in larger fish. Spawning probably occurs earlier in northern waters and progressively later in southern waters, where late September and October is the date for reproductive activity (bottom temperature approximately 10° C.). Eggs are laid in crevices in rocky areas, for the most part within the 30-fathom contour, and are protected by one or both parents. The period from fertilization to hatching is three and one-half months in northern waters, two and one-half months off southern New England. Length-frequency studies demonstrate selectivity of the trawl net for size and sex, and illustrate the possibilities for misinterpretation when the curves are not divided into male and female components; age determinations by this procedure have severe limitations. Otoliths do not grow in direct proportion to the fish, but can be used as age indicators. Southern New England ocean pout average roughly 5-8 cm. at six months, 11.5-15 at one year, 16-20 at 18 months, 31 at three years, 48 at five, 81 at 10, and 97 at 15. Northern fish grow much more slowly and do not attain as great a size. The commercial catch is composed mainly of four- to ten-year-olds. Age at maturity was determined by the study of sections, the estimation of the per cent of the weight of the fish occupied by the weight of the gonads over the size-range of the population at one date, comparative egg measurements from individuals of different sizes, and length-weight analyses of the separate sexes. Below 25 cm. all male ocean pout are immature; above 39 nearly all are mature. The smallest size at which females become mature is approximately 45 cm. (5th-6th year); all are mature at 65 (7th-9th year). There is a slight preponderance of males over females. Males leave the summer and fall

habitat in advance of females; they probably also return to the rocky bottom in late spring and early summer first. Younger fish apparently do not take part in seasonal movements in large numbers until after the third year of life. Vertebral counts of individuals from different localities show significant differences, the means being progressively lower from northern Cape Cod (140.25) to Long Island Sound (136.11). However, the sample from the Bay of Fundy is the lowest of any (134.46); the possibility of two major genetically separate populations is discussed.

Feeding habits. Stomach contents of 21 samples (over 850 fish) have been analyzed in detail. Over 80 organisms were identified, and relative volumes of the major items are presented on a percentage basis. Among the more common forms are Gammaridae, *Echinarachnius parma*, *Cancer irroratus*, *Unicola*, *Cardium pinnulatum*, *Pecten* and *Yoldia*. Ocean pout are not piscivorous. The percentage of empty stomachs was generally low. Acanthocephala occurred with a fairly high degree of regularity; Nematoda were more common in northern than in southern fish. Search for secondary hosts or vectors of parasites should be facilitated by this study.

Incidence of parasites in the flesh. The microsporidian, *Plistophora macrozoarcidis* Nigrelli, is the parasite of greatest commercial importance. It may manifest itself as individual trophozoites or moderate and large lesions. Other parasites are *Chloromyxum clupeiidae*, metacercarial cysts and *Porrocaecum decipiens* (?) Krabbe; yellow bodies of unknown function were also observed in numerous specimens. The incidence of infection was determined by detailed examination of individual filets with the aid of transmitted illumination. Candling, as practiced commercially, is inadequate. There is no evidence from these studies that infections by *Plistophora* increase in size in frozen filets. *Plistophora* was found only in muscle, and was detected in all samples from Canada to Long Island Sound. Large lesions were relatively few in fish from northern Cape Cod and much more common in areas to the south and west. Discussion as to how *Plistophora* may be transmitted is included. There is a higher incidence of infection anteriorly than posteriorly. Younger fish are less infected than older, but individuals apparently live for years while infected with *Plistophora*. The spores do not appear to be liberated through the skin of living ocean pout. There was no apparent correlation between incidence of infection and sex or vertebral counts, or between size of lesion and incidence of infection per sample. The time and situation in which infections are most likely to be contracted, the possibility of an intermediate host or vector, the question of whether or not *Plistophora* manifests itself in epidemic form, etc., are discussed.

Conclusions. A combination of the seasonal movements, life history, general shape and hardness of this fish assures it an unusual degree of security. Apparently the stock can be fished more intensively than the level resulting in the 1943-1944 catch without detriment. However, continued observation of landings and age composition of the catch is essential. Successful marketing is primarily dependent on efficient candling; this species should never be sold "round"; filets should be skinned before examination. Small infections (individual trophozoites) appear to be inconsequential in relation to marketing. The northern Cape Cod fishery should continue to expand; once the standards of commercial candling have been raised, the whole fishery should proceed with the development begun in 1943-1944.

ACKNOWLEDGMENTS

Throughout this investigation we have received much assistance, and it is with great pleasure that we take this opportunity to express our appreciation to all those who have contributed to this paper in one form or another. Without the help so generously given by so many, the completion of the work would not have been possible at this time.

The Connecticut State Board of Fisheries and Game, through the interest of its Superintendent, R. P. Hunter, who early in 1943 called our attention to the need for work on this species, supplied funds for the purchase of the many samples of ocean pout needed in a quantitative study of this nature. Similarly the State Board made possible the employment of Dorothy A. Baitzell and W. H. Yudkin as temporary assistants who helped in the collection and analysis of the raw data in 1943 and 1944. Also Capt. Walter Palmer, Capt. Frank Banning and Mildred K. Bartle of the State Board rendered valuable advice and aid at various times in the course of the work.

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The Woods Hole Oceanographic Institution, which by its friendly interest and cooperation has done much to further our work on the utilization of marine resources, contributed indirectly to the progress of this investigation by awarding a fellowship at the Bingham Oceanographic Laboratory in the latter part of 1943 to H. E. Warfel, who subsequently became a member of the regular staff.

To W. C. Schroeder, Museum of Comparative Zoology at Harvard College, we owe thanks for much pertinent information and for the loan of embryos shown in Fig. 9 and discussed on page 77. W. H. Chute of the Shedd Aquarium in Chicago kindly provided the illustration for Fig. 8. A. W. H. Needler and E. G. Rigby, of the St. Andrews Biological Station, New Brunswick, Canada, arranged for the collection of the sample of ocean pout from the Bay of Fundy in the summer of 1943.

Without the close cooperation of the fishing fleet it would have been impossible to obtain the many samples and basic data which were essential in this investigation. In the present study we have had the benefit of generous assistance and oftentimes useful information from numerous individuals associated with the fishing industry. At Stonington, Connecticut, Capt. Ellery Thompson of the vessel "Eleanor," whose cooperation has been invaluable in much of the work of this laboratory in recent years, has collected many ocean pout from the Block Island area. Other captains and their crews in the Stonington fleet who have assisted materially are: W. H. McLaughlin of the "Marise," Aldo and Roscoe Bacchiocchi of the "Baby II," A. L. Roderick of the "Rita," and S. W. Stenhouse of the "Nathaniel B. Palmer."¹ We also acknowledge the help of J. B. Bindloss, John George, John Rogers, and Raymond Scheller. At New Bedford, Massachusetts, W. F. Royce, Warren Landers and Edmund O'Neil of the U. S. Fish and Wildlife Service aided in obtaining material and otherwise furthered the investigation on several occasions. To Capt. E. O. Sanchez and crew of the "Heedja" we are grateful for valuable small specimens. P. J. Murphy and Henry Carmos of the Dartmouth Fillet Co., William Curran of the Sea View Fish Co. and Leo Allen of the New Bedford Fillet Co. also cooperated in supplying specimens from the New Bedford region. At Provincetown, Massachusetts, Capt. Manuel Dutra of the "Viola D" provided important samples of ocean pout from time to time, and thus made possible the inclusion of highly significant data from northern Cape Cod in this paper. Also at this port, Samuel Kurz and Daniel Williams of the Star Fillet Co., as well as Frank Rowe of the Atlantic Coast Fisheries Co., gave much assistance.

A number of students have had a part in this investigation. We owe the detailed analysis of the stomach contents entirely to Pfc. F. E. Smith, who, with the assistance of L. C. Park and E. H. Uhlenhuth, did this study as a special problem in Zoology while at Yale as a member of the Army Specialized Training Program for premedical students. Without his careful work and identifications it would have been impossible to incorporate the material used in the section on Feeding Habits. Others who have contributed are Pfc.'s D. H. Glew, Jr., who is responsible for Fig. 10, G. E. Landis, Jr., and R. D. Metzger,

¹ Sunk at sea April 6, 1945, with the loss of three of her crew by an explosion caused by an aerial bomb which was brought up in the net.

as well as R. S. Cheves, Jr., O. D. Deex, and Hans Steinherz. A collection of unusual interest from the middle of Long Island Sound was made by J. E. Morrow, Jr., former graduate student now serving in the U. S. Marine Corps, on board the "Jane" under Capt. E. C. Post of West Haven, Connecticut.

We have also leaned heavily on the advice and help of the entire staff of the Bingham Oceanographic Laboratory. We are particularly grateful to the following: H. E. Warfel, for generous assistance both in the field and laboratory, as well as in the preparation of the length-weight equation and the analysis of the data presented in Table XI; Grace E. Pickford, who has given invaluable counsel in regard to the parasitological problems; Elizabeth A. Morrow, former secretary and now serving in the Women's Auxiliary Corps of the U. S. Army, for help in the laboratory, especially in relation to the infection study; Louva Henn, whose patience in the performance of far more than customary secretarial routine has been no small asset; and M. D. Burkenroad and E. F. Thompson, both of whom have given stimulating advice and assistance. We have been fortunate also in receiving the help of various members of the Osborn Zoological Laboratory and the Peabody Museum at Yale University; we wish especially to acknowledge our indebtedness to Mary Carbone for histological preparations, to Percy A. Morris for photographic work and identification of molluscs and to Eleanor Smith and Joyce E. Peck for secretarial assistance.

When this paper was in galley proof we also received the generous comments of C. L. Hubbs of the Scripps Institution of Oceanography, who made many pertinent suggestions and corrections for which we are most grateful.

Finally, we wish to make it clear that while we have had the benefit of many individuals' advice and help, we assume complete responsibility for the material presented herein.

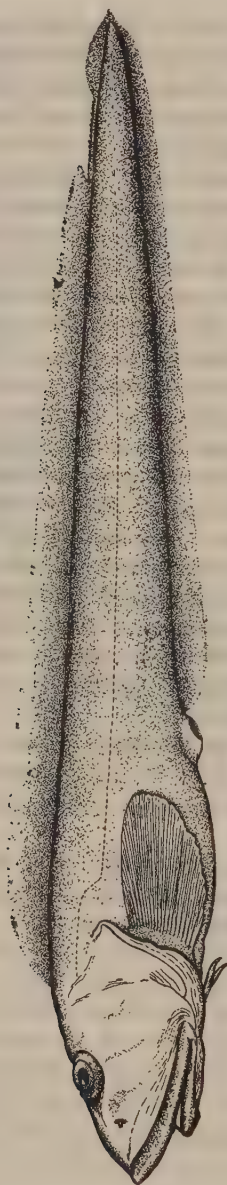


Figure 1. The ocean pout, *Macrzoarces americanus*. Drawn from a specimen 73.5 cm. long taken March 19, 1944, four miles NW. of Sandy Point, Block Island, Rhode Island, at approximately 20 fathoms.

THE PROBLEM

Although abundant and commonly taken by fishermen from New Jersey to the Bay of Fundy, the ocean pout, *Macrozoarces americanus* (Bloch and Schneider), never attained more than an extremely limited market status until 1943. In that year, partially as a result of war conditions, an attempt was made to market this species in fillet form. That this product met with immediate favor is clearly indicated by the fact that over 5,000,000 pounds of ocean pout per year were landed in 1943 and 1944. The most intensive fishing was carried on by relatively small trawlers and draggers in the coastal area between Provincetown, Massachusetts and New York City, and was confined in the main to the period from January to June.

Almost at the inception of the fishery and just as the landings of the fleet were reaching major proportions, it became apparent that the flesh of the ocean pout was not infrequently rendered unfit for market by the presence of large sores sometimes an inch or more in diameter. As always, under such conditions, rumor ran rife; the sores were described as "tumors," "cancers," "boils," etc., and the consumption of flesh containing them was reputed to cause violent illness. Factual information regarding the sores was not available. Large shipments of ocean pout were declared unfit for human consumption by municipal and federal public health officials, and this in turn acted as a deterrent to the fishery so that the landings of ocean pout in 1943 and 1944 do not represent the extent to which this species could augment the nation's fisheries productivity under more intensive effort. Then in the spring of 1943 R. F. Nigrelli, Parasitologist of the New York Zoological Society, established the fact that the sores were caused by a protozoan parasite, tentatively identified as *Ichthyosporidium* sp., and subsequently (with more adequate material at hand) determined as a new species belonging to the subclass Cnidosporidia, order Microsporidia, genus *Plistophora*. It therefore became apparent that the danger of actual infection in humans from consuming the parasitized flesh of the ocean pout was slight, since there is no known case of a sporozoan of the sort indicated above which affects both cold- and warm-blooded vertebrates; furthermore, there is no evidence that such a disease can be transmitted from fish to man. On the other hand, it was recognized that there might be danger of mild illness with the typical symptoms of food-poisoning from the consumption of flesh in

which the proteolytic action associated with major infections had gone sufficiently far. Probably the best evidence that ocean pout fillets are a product which can be marketed satisfactorily, and with no more danger than that from many other similarly parasitized and marketed fish, is provided by the magnitude of the catch, over 10,000,000 pounds in 1943 and 1944, and its subsequent consumption without apparent ill effects. Nevertheless, the infections present definite marketing problems. Thus it has been indicated by Sandholzer, Nostrand and Young (1945) (pp. 142, 199) that while some of the fillets that are frozen appear uninfected on inspection of the fresh flesh, these same fillets may show lesions on their removal from the freezer at a later date; the same workers also stated that lesions in fillets " . . . appear to continue to increase in size and number in fillets stored at 8° F. for two or more days." These unexpected findings, not duplicated by other investigators, do, however, point to the economic problems involved in handling this species. In all events, without careful inspection there is always the chance that infected and unsightly fresh fillets may reach the market. The adverse effect of the sale of a product of obvious poor quality to the fisheries industry as a whole cannot be over-emphasized.

In view of the foregoing and the dearth of information on the life history, habits and parasites of the ocean pout, it seemed imperative that a detailed investigation be initiated immediately. Federal and other organizations were apparently unable to give the matter the attention it merited, due to the man-power shortage and the pressure of other duties in the war emergency period. It seemed obvious, therefore, that the investigation should be undertaken by the Bingham Oceanographic Laboratory (whose geographical position was particularly fortunate for the study of this species), in cooperation with specialists who were able and willing to contribute to the solution of the whole problem.

The primary objectives were as follows. 1. To collect as much data as possible about the life history, availability and catch statistics of this species in order to provide information for the rational utilization of the stock. This information is essential as a basis for recommendations concerning the intensity of fishing that the stock can stand, both from the point of view of its present yield and its ultimate conservation. As pointed out previously (Merriman, 1944), the fact that work on this species was begun almost as soon as it became an important

element in the commercial landings is of considerable significance in itself, since most fishery investigations in the past have been undertaken only when the stock concerned was so depleted as to cause alarm. 2. To gather as much information as possible about the protozoan parasite of this species and its effect on the marketability of ocean pout fillets, with particular reference to the seasonal and geographical incidence of infection. In regard to the second objective it was anticipated that the results might lead to one of the three following conclusions. a.) That the fishery need be in no way curtailed and that adequate inspection would eliminate the possibility of unsuitable fillets appearing on the market. b.) That the fishery should be limited to certain areas where the percentage of infection was sufficiently low to enable the sale of a product of high quality which would augment fisheries productivity as a whole, albeit to a lesser degree. c.) That the incidence of infection as well as the difficulties of proper inspection were such as to render the commercial exploitation of this species impractical. The opinion of certain officials and organizations to the contrary—witness the embargo placed on ocean pout either landed at or shipped to the City of New York in early 1945—it shortly became evident that the last conclusion could be reached only in the absence of full factual information or because of indifference toward attempts to effect the full utilization of available marine resources, even in emergency times.

While many questions and problems associated with the life history and economic aspects of the ocean pout still remain to be answered, we believe that sufficient basic information is presented herein to make possible sound conclusions based on fact as to the general utility and limitations of this species.

ECONOMIC CONSIDERATIONS

As indicated earlier (p. 9), prior to 1943 the market for ocean pout was restricted to a few thousand pounds which went primarily to the Italian trade.¹ Before this time it had been sold "round" under various names, all of which included the term "eel" (*e. g.*, "congo" or

¹ Fishing Gazette, 60 (3): 34, March, 1943. This article refers to the ocean pout as the "conger eel," and includes an illustration of the true conger, *Conger oceanicus*, although it deals solely with *Macrozoarces americanus*, thus affording an example of the confusion resulting from the careless use of common names mentioned on page 34.

"conger eel," "eelpout," etc.). The name alone was sufficient to place this species under a distinct handicap on the market, since many people have an aversion to anything eel-like; but its general appearance, even when gutted, was so unattractive as to limit its sale still further. Despite the fact that fishermen and others knew that the fish was available in large quantities in New England, New York and New Jersey coastal waters, no serious or concerted effort was made to use this resource until 1943, even though Clemens (1920) had pointed out its potentialities in Canadian waters. Some idea of the relatively unimportant market status and the obscurity of this species is afforded by the fact that from 1939 to 1942 its annual landings by Connecticut boats averaged roughly 1000 pounds, and that in 1942 its total receipts on the New York market amounted to only 5,535 pounds (Table I).

TABLE I. NEW YORK RECEIPTS OF OCEAN POUT BY MONTHS IN 1942, 1943 AND 1944*

	1942	1943	1944
January.....	4,965 lb.	12,612 lb.	776,723 lb.
February.....	147	75,700	456,365
March.....	100	375,660	339,001
April.....	100	287,588	98,562
May.....	—	27,830	1,325
June.....	—	1,183	—
July.....	—	—	—
August.....	—	—	—
September.....	31	—	—
October.....	100	—	—
November.....	92	—	—
December.....	—	36,876	100
Totals.....	5,535 lb.	817,449 lb.	1,672,076 lb.

* Data from U. S. Fish and Wildlife Service Market News Service sheets. Includes receipts by rail, truck and fishing craft as reported by the wholesale dealers in the Salt-water Market, New York City. Excluded are local cold-storage withdrawals and direct shipments to hotels, restaurants and retailers.

In January 1943, through the action of the Fishery Council of New York and other groups, this fish was placed on the market in fillet form, and in that year it was sold primarily under the name "ocean pout," thus eliminating the two most obvious elements preventing its wider acceptance. Well planned publicity further aided its sale. These actions met with immediate success.

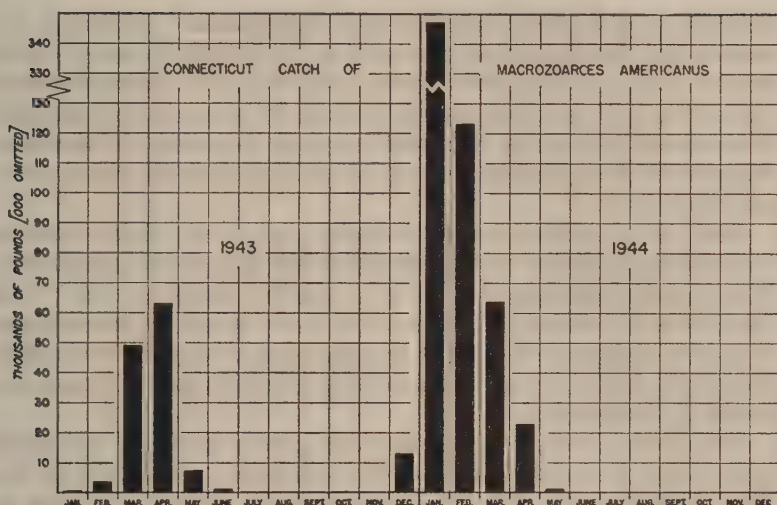


Figure 2. The Connecticut catch of ocean pout by months in 1943 and 1944 expressed in thousands of pounds (*i. e.*, 000 omitted). Data taken from U. S. Fish and Wildlife Market News Service sheets and Connecticut State Board of Fisheries and Game records.

Landings and availability. The increased demand resulted in a sudden, intensive fishery. The Connecticut fleet alone landed over 110,000 pounds of ocean pout in March and April of 1943; the receipts on the New York market jumped to over 800,000 pounds in 1943 and to nearly 1,700,000 pounds in 1944 (Table I). In considering these figures it should be realized that the fishery is highly seasonal, being confined essentially to the first six months of the year, so that the figures for any particular year actually represent the take in a six- or seven-month period (p. 40). Perhaps the most graphic illustration of the sudden magnitude and intensity of the ocean pout fishery is afforded by the figures from New Bedford, Massachusetts, the port at which the largest landings were made.¹ From January to June 1942 the ocean pout was not important enough to be listed as a separate species; instead it was included under "Miscellaneous," a category including "mostly unspecified species, but also some specified as cusk, eelpout, goosefish, rosefish, shad, sharks, skates, and squirrel hake,"

¹ Data from U. S. Fish and Wildlife Service Market News Service (Jan.-June, 1942, for New Bedford).

the sum total of which amounted to 16,825 pounds. In 1943 in the same period the landings of ocean pout at New Bedford were 3,179,129 pounds, valued at \$100,057.¹ One reason why New Bedford became the leading port for ocean pout is because the major part of its large fleet concentrates on the yellowtail (*Limanda ferruginea*), a species of flounder which occupies grounds on which ocean pout are also particularly abundant.

Table II gives the landings of ocean pout at the major ports in Massachusetts, as well as the receipts on the New York market from Rhode Island, Connecticut, New York and New Jersey in 1944.² The total catch for 1944, 5,219,505 pounds, does not include the landings at certain smaller ports as well as shipments to markets other than New York, so that in round numbers the 1944 catch probably approximated 5½ million pounds.

It is quite certain, however, that the great majority of the ocean pout caught in states other than Massachusetts were shipped to the New York market. The totals shown at the bottom of Table II therefore provide evidence of a general sort on the relative productivity of the different areas in which they were caught, *under the conditions existing in 1944*. But these totals in no way indicate the volume which might have been taken under conditions conducive to a more intensive fishery. In fact there is much evidence that the stock of ocean pout is capable of producing far more than 5,500,000 pounds annually. For example, a comparison of the landings in 1943 and 1944 in March and April at New Bedford illustrates this point:

	1943	1944
March.....	983,400 lb.....	1,033,600 lb.
April.....	1,424,377 lb.....	216,800 lb.

The sharp drop in the New Bedford catch in April 1944, at a time of year when ocean pout are available in abundance, is attributable to

¹ The catch by months was: Jan., 6,940 lb.; Feb., 395,197 lb.; Mar., 983,400 lb.; April, 1,424,377 lb.; May, 369,215 lb.

² The New York market also had some receipts from Massachusetts, but these are not included in this table since the landings of that state are given by ports, and the inclusion of the monthly poundages received by New York from Massachusetts would introduce an error in the totals listed in the right-hand column because those amounts would be counted twice. The actual receipts on the New York market from Massachusetts in 1944 were: Jan., 119,535 lb., Feb., 144,065 lb., March, 121,111 lb., April, 12,425 lb.

TABLE II. MAJOR LANDINGS OF OCEAN POUT AT DIFFERENT PORTS IN MASSACHUSETTS, AND RECEIPTS ON THE NEW YORK MARKET FROM RHODE ISLAND, CONNECTICUT, NEW YORK AND NEW JERSEY BY MONTHS IN 1944 EXPRESSED IN POUNDS*

	Massachusetts				New York Receipts				Totals
	Gloucester	Provincetown	Woods Hole	New Bedford	R. I.	Conn.	N. Y.	N. J.	
January.....	25,500	284,000	59,500	547,500	125,155	346,960	152,837	16,236	1,557,688
February.....	5,000	66,000	174,100	1,158,630	87,464	123,045	83,433	18,358	1,716,030
March.....	1,000	92,000	175,300	1,033,600	31,685	63,896	113,099	7,855	1,518,435
April.....	300	52,000	24,600	216,800	1,117	22,591	44,877	1,817	364,102
May.....	100	16,000	.....	46,000	.....	1,000	50	.....	63,150
June.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
July.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
August.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
September.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
October.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
November.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
December.....	.....	.....	.....	.....	.....	.....	.....	100	100
Totals.....	31,900	510,000	433,500	3,002,530	245,421	557,492	394,296	44,366	5,219,505

* Data from U. S. Fish and Wildlife Service Market News Service sheets. See Table I for explanation of New York receipts.

the creation of a 3-cent ceiling price by the Office of Price Administration on March 23, 1944. It is a conservative estimate that the landings at this port alone would have been approximately 1,000,000 pounds higher in one month had it not been for this action. Further evidence that the stock is capable of producing much more than 5,500,000 pounds *per annum* comes from the fact that as a general rule this species was not the primary object of the fishing fleet. Rather, it was taken by trawlers which were principally after flounders (*L. ferruginea* or *Pseudopleuronectes americanus*), and instead of discarding most or all of the ocean pout as "trash," this species was brought to market at a time when the need for increased fisheries productivity was acute. There is no way of estimating what the potentialities of the stock might be if this species became the primary object of a large fishery, just as it would have been impossible to predict the present magnitude of the catch of the rosefish (*Sebastes marinus*) on the basis of information available in the early 1930's.¹

"Trash" fish and latent resources. It is obvious from the foregoing account that in 1943 and 1944 much progress was made in utilizing the ocean pout, a fish which had been considered essentially as a "trash" species up to this time and had been discarded in large quantities. The fundamental importance of this increased utilization is two-fold.

First, the addition of approximately 10,000,000 pounds of ocean pout to the nation's fisheries productivity was a notable contribution in a wartime emergency period. The need for additional sources of fish and sea foods to meet wartime demands was acute, and the inability to meet those demands intensified existing and widespread critical shortages in the food industry as a whole.² Lack of manpower

¹ A decade and a half ago the rosefish was considered a "trash" fish. In 1932 and 1933 the landings averaged less than 200,000 lb. valued at just over \$2000; in 1934 they were nearly 2,000,000 lb. valued at approximately \$18,500; in 1935 and 1936 they averaged 17,000,000 lb. valued at \$184,000; and in 1937 and 1938 they averaged over 60,000,000 lb. with a value of nearly \$850,000 (Fiedler, 1934-1941). In the last three years the landings have exceeded 100,000,000 lb. annually (see Fishing Gazette, 1944 Annual Review Number, 61 [12]: 148, 1945).

² In 1941 the commercial fisheries of United States and Alaska produced their greatest total catch, approximately 5,000,000,000 lb.; in 1942 the figure dropped to 3,700,000,000 lb.; in 1943 United States and Alaska were called on to produce 6 to 7,000,000,000 lb. to supply the needs of the armed forces, allies and civilian population, but the catch amounted to only 4,000,000,000 lb.; and in 1944 the catch was of

and the reduction in the size of the fishing fleet due to the appropriation of vessels by the U. S. Navy were unquestionably contributory factors in the failure of the fisheries to produce the requisite amounts. But the saving of "trash" species at sea requires little more effort and no extra manpower under most circumstances, and most of the filleting and processing on shore is done as effectively by women as men.

Second, any tendency or trend toward the greater use of "trash" species is of the greatest significance because it implies a fuller and better utilization of available marine resources. It has long been recognized that the wastage in certain fisheries in terms of species that are discarded, but which can be used, is of major proportions, but accurate figures have been lacking for the most part. However, Merriman and Warfel (1944), in an analysis of a southern New England trawl fishery from July 1943 to January 1944, showed that only 36 per cent of the catch by weight were fish that were regularly marketed, 11 per cent were in an occasionally-marketed category, and 53 per cent were discarded as "trash." In other words, more pounds of fish were thrown away than were kept.¹ It should be added, however, that in 1944 the trend toward greater use of what were formerly considered as "trash" fish increased somewhat. Nevertheless, the fact remains that conservative estimates by the staff of the Bingham Laboratory place the volume of usable fish discarded by Stonington,

much the same size, but still over a billion pounds short of wartime demands as stated by representatives of the War Food Administration [data from Fishing Gazette, 60 (8 and 9), 1943 and 61 (2 and 12), 1944]. In March 1945 Coordinator of Fisheries, Harold L. Ickes, reported that, "The United States Fishing industry, in spite of restoration of its fleet to nearly normal size, probably will be unable to produce enough fish and shellfish in 1945 to meet the goals established by the War Food Administration for the current year, . . ." (U. S. Fish and Wildlife Service Market News Service, March 21, 1945).

¹ Of the discarded species, over 85 per cent were skates and sculpins (*Raja dia-phanes*, *erinacea*, and *stabuliforis* and *Myoxocephalus octodecimspinosus*). That skates have long yielded over 50,000,000 pounds annually to England, Scotland, Wales and Ireland is well known (Howell, 1921 and Report of the U. S. Tariff Commission to the U. S. Senate on Subsidies and Bounties to Fisheries Enterprises by Foreign Governments, 116, Second Series, p. 96, 1936). That sculpin-like fish can be handled successfully is shown by the fact that *Scorpaena guttata*, a fish presenting marketing problems similar to those of *M. octodecimspinosus*, provides approximately 100,000 pounds annually from southern California waters (Barnhart, 1936, and 37th Biennial Report of the Division of Fish and Game, State of California Department of Natural Resources, pp. 96 and 111, 1944).

Connecticut vessels, a relatively small fleet, at approximately 5 to 10 million pounds annually in the first half of the present decade.

The subject of "trash" fish inevitably leads to the whole question of latent and unused fisheries resources. It is difficult to provide overall estimates as to what extent these relatively untapped resources could add to the nation's productivity, and how well the different stocks would stand the strain of exploitation. Croker (1942) and Chapman (1942) have discussed the problem on the Pacific coast and have indicated the possibilities for expansion in those waters.¹ While there is good reason to believe that there are not equivalent opportunities for expansion on the Atlantic coast, it is perfectly evident that the fisheries resources as a whole in this region have not even approached the level of utilization of which they are capable.

The factors which control the extent to which aquatic resources are utilized are many and complicated. Historically speaking, and in the most elementary terms, the development of the fisheries probably follows a fairly regular, broad pattern in different localities. The initial species of fish which are exploited are those that are abundant, easily available and of sufficient size and quality to make them immediately worth primary attention. These become best known to the consumer and almost always remain in demand. In the course of the development of these fisheries, two things are likely to occur. The first is the partial exploitation of other abundant and marketable species. The second, under the conditions of an intensive fishery, is an eventual lowered return per unit effort or decreased abundance of the primary species; this may simply be a manifestation of marked fluctuations in numbers due to natural phenomena over which man exerts no control, or it may actually reflect the result of overfishing. The second may accelerate the first process—*i. e.*, a causal relationship may exist. In all events, the result is that an increased number of different kinds of fish are landed. The length of time it takes to reach this condition and the extent of the variety of species used differ in each locality; these matters are dependent on many factors such as the demand, the ability of the primary species to stand intensive ex-

¹ For example, Chapman says, "We hear much of the tremendous fisheries of Alaska, but some 98 per cent of the product of those fisheries are salmon, herring, and halibut. Of the 500-odd species of fish, and numerous edible shell-fish, inhabiting the waters of Alaska and the Bering Sea only some 27 are fished upon commercially, and only 14 of these produce a million pounds or more annually."

ploitation, the availability of the secondary types, the progress in technological and marketing techniques which enables the wider distribution of fisheries products, etc. Little by little, then, the variety of fish reaching the public increases. The more this trend continues the more closely is the rational utilization of marine resources approached—at least in one sense of the word. Ideally the tendency would be to distribute the fishing effort more evenly over a wide variety of species; under these conditions there would be less chance of the depletion of certain species due to over-concentration on them, and the resultant economic distress for those engaged in the particular fisheries concerned. But in general the fisheries never really approach this ideal condition because attempts to catch and market new types are usually made only when the dread of depletion looms large with the primary species, or in emergency times (*e. g.*, ocean pout). In short, the stocks of the original species become unable to meet the demand, either because of overfishing (a lowered return per unit effort), or because of fluctuations in the natural supply which force an attempt to market new species. In practice, then, the exploitation of all the available species does not occur simultaneously, but only over long periods of time, and is conditioned by the primary supply and the demand. It would be unreasonable to expect that the ideal distribution of effort over all the available species would occur *ab initio*, or even at a very early stage in the development of the fisheries. But no matter what the stage of exploitation of the various species in any area, it is never too late to aim at the full and rational utilization implied by the distribution of effort over all the forms that are available.¹ The sooner this is done, the greater the chances that the individual stocks will stand the strain of the fishery better, because one or a few stocks need not be subject to such an intensive drain. In the case of the Atlantic coast trawl fisheries there is still ample opportunity for improvement along these lines. The history of the ocean pout in 1943 and 1944 affords a good case in point. Similarly, it is an

¹ We should add, however, that natural competition between species is probably a vital factor in this matter. Overfishing of a few species may lead to an increase in the unutilized forms. Partial equilibrium may then be restored by removing some of the excess of the previously unutilized species, so that there may actually be a gain in the total poundage taken through the "spread" of the fishing effort. Also, there may be an increase in the natural production and in the catch of the favored species.

obvious corollary of this discussion that once the prejudice of the fishermen against handling a "trash" species has been overcome, and once the marketing problems have been solved, it is extremely shortsighted to do anything that may act as a deterrent to the fishery or the market.

Before continuing with the application of these principles to the ocean pout, let us examine some of the reasons why the marketing of a great variety of species is so slow of accomplishment in the development of the fisheries in any particular region. One obvious reason is that the primary types, those that are exploited first, are usually abundant and prolific, so that in most cases they are able to supply the demand over long periods. Important as is this exploitation, it has two disadvantages to the ideal situation where the fishing effort is spread over a greater variety: 1.) the consumer does not become "educated" to the different flavors of many different species, and 2.) the fishermen tend to become prejudiced against other species than those they seek in particular, especially if these others must be sorted from the rest of the catch. An added reason why the secondary types are not exploited early in the development of the fishery is because they frequently require special handling of one sort or another, and the technological and marketing problems cannot be overcome immediately. Still another factor in the situation is to be found in the poor handling of fish between the net and the consumer. In this country the lack of effort and care in getting the fish to the consumer in as nearly a perfect condition as possible has been "the greatest single deterrent to the marketing of most fish," (Chapman, 1942).¹ Only a relatively small fraction of the public appreciates the value of the really fresh product. Consumers often ask only for "fish," not for a particular kind whose flavor is especially attractive, because the condition of the product is so poor by the time it reaches the market that the different species are all too often indistinguishable in taste. This is likely to mitigate against the wide use of the *variety* of fish that are available. The whole future of the fisheries industries lies in their

¹ This is surprising because the success of the industry so obviously depends on getting its products, which at best are extremely delicate, to the consumer in prime condition. The careful handling of fish on British trawlers in the North Sea as contrasted with that on trawlers in the North Atlantic is striking (Merriman, 1932); the practice of letting fresh fish stand for several days in the barrels in which they are packed so that they get soft for easier filleting is another case in point.

ability to market quality products, and in the education of the public to the varieties and different flavors of fish. Competing foods have gained a great advantage by more extensive and better planned advertising. Just as the consumer asks for specific kinds of meats, vegetables, or even breads, because he has particular preferences, so should he ask for different kinds of fish because he knows and appreciates their special qualities and different flavors.

The gain to the fishing industry in this country from the wider utilization of available resources and the marketing of a greater variety of quality products should work in two directions. The first of these is the diffusion of fishing effort over more species so that the intensity of the drain on the primary stocks is alleviated and the economic security of the fishermen and others is therefore on a less hazardous basis. The second is the badly-needed education of the consuming public as to the wide assortment of fisheries products that exist so that these commodities can compete with other foods and the annual per capita consumption may be maintained at least at its present level.¹

Price control and marketing problems. The economic factors governing the sale of ocean pout in the emergency period from 1943 to 1945 are highly significant in the light of the preceding discussion. Much of the following section is concerned with the efforts at price control by the Office of Price Administration. In any consideration of this subject, it is important to keep in mind both that the very nature of the industry made it among the most difficult to regulate (footnote, p. 26), and that the information on which ceilings were based was not immediately available but had to be obtained from a variety of sources in cooperation with the Office of the Coordinator of Fisheries.

As indicated earlier (p. 14), in 1943 the average price received by fishermen at New Bedford, the port where the largest landings were made, was 3.1 cents per pound; and in Boston in the period from February to April 1943 the price ranged from 1 to 6.1 cents per pound.² This was, of course, the first year that ocean pout came on the market in more than limited quantities, and it is therefore reasonable that the average price should have been relatively low until the fish became

¹ The annual per capita consumption of fish in United States is approximately 10 to 15 pounds, as contrasted to 35 in England and over 50 in Sweden.

² Data from Fishing Gazette, 60 (3, 4, and 5), 1943.

better known and the demand increased. Furthermore, *average* prices over long periods sometimes fail to provide a fair basis of evaluation, and obviously much depends on the precise manner in which the averages are determined. For example, ocean pout unquestionably have a higher value in February, when other species are relatively scarce, than they have in May and June when other fish are more available. Be this as it may, the Office of Price Administration in the spring of 1943 attempted to place a ceiling price on the frozen fillets of ocean pout with the results indicated below in an excerpt from the *Fishing Gazette*, 60 (5): 90, May, 1943.

EELS GET FREE:—Ain't science wonderful? At least New Bedford's fishing industry thinks so.

Gloom settled along the waterfront the other day when OPA announced price ceilings on the conger-eel (frozen variety) ranging from 15 to 19 cents. Fish buyers and filleters have been doing a landoffice business in conger-eels, ever since some bright lad discovered that this newly-known and palatable fish was abundant in certain areas along the Cape.

But William F. Royce, area co-ordinator for the U. S. Fish and Wildlife Service, solved all their difficulties. It seems fishermen have been throwing the term "conger-eel" around for an entirely different species of fish, more accurately called the ocean pout.

If OPA intended to put a ceiling on ocean pout, the Government boys haven't a leg to stand on according to Mr. Royce.

OPA's conger-eel is definitely classified *leptocephalus linnaeus*, whereas the ocean pout caught locally is classified *zoarces anguillaris*. So—no *zoarces* on OPA's list, no ceilings!

And all the fish dealers have gone back to freezing the good old eel pout like mad.

OPA better get its *anguillaris* straightened out.

No further attempt to place ceiling prices on ocean pout was made in 1943.¹ This species disappeared from the catch in the late spring and did not reappear in significant numbers until the winter, thus following its regular pattern of seasonal abundance (p. 40). Ocean pout returned to the market again in December 1943, and the largest monthly landings of this species were made in January and February 1944 (Tables I, II). In this period the price to the fishermen ranged all the way from 1 cent to \$2.50 per pound.² It was common practice on the part of the buyers at this time to bid fantastic prices for a

¹ But price ceilings were placed on many of the North Atlantic species on July 13, 1943, under Maximum Price Regulation No. 418.

² Data from U. S. Fish and Wildlife Service Market News Service sheets.

variety of species which were not under ceiling prices (among them ocean pout) in order to obtain the rest of the price-controlled catch. Thus Fishery Products Report No. 56 of the U. S. Fish and Wildlife Service Market News Service (March 9, 1944) stated:

There was an instance in which a wholesaler had to pay as high as \$500 for one fish (a skate) to obtain an entire boatload of a type of fish under price control. In several other instances a few pounds of uncontrolled fish were auctioned off to wholesalers from a boatload of fish otherwise under ceilings with the understated consideration that the highest bidder got the entire boatload at ceiling prices after being the high bidder for the few pounds of non-ceiling fish.

In an effort to curb this practice the Office of Price Administration issued Amendment No. 26 to its maximum Price Regulation No. 418. This amendment, effective March 13, 1944, established price limitations on the sales of fresh fish and seafood not under specific ceilings when sold by fishermen and wholesalers in combination with varieties for which maximum prices had been fixed. More specifically this amendment included a ceiling of the current market price, or 5 cents a pound (whichever was less) on sales or purchases of previously uncontrolled fish or seafood, by or from producers, if at least 25 per cent of the weight of the total fish or seafood involved was under price control.¹ This amendment was followed almost immediately by Amendment No. 27 to Maximum Price Regulation No. 418, issued and effective March 18, 1944; it placed a 3-cents-per-pound ceiling on ocean pout in the "round" (uncleaned). The U. S. Fish and Wildlife Service Market News Service for March 23, 1944, reported that:

In recent weeks ocean pouts have sold at prices as high as \$3 per pound ex-vessel. Exorbitant prices were paid fishermen for this fish in order to secure for the buyers supplies of controlled fish. Recently, Amendment No. 26 to the regulation set a ceiling of the current market price or 5 cents per pound, whichever is lower, for sales of uncontrolled species in combination with sales of controlled varieties. The 5 cent cover-all, however, *is far above the 1942 average for sales by producers* [italics ours]. This amendment brings

¹ U. S. Fish and Wildlife Service Market News Service, March 9, 1944. Other limitations included the following. 1.) A ceiling of the current market price for sales or purchases by or from wholesalers of previously uncontrolled fish when sold in combination with controlled fish. 2.) A prohibition against offering, selling or delivering of fresh fish or seafood on condition that the purchaser is required to purchase some other commodity or service. 3.) A prohibition against falsely or incorrectly invoicing fresh fish or seafood.

about a price reduction of 2 cents per pound in sales of the round and proportionately greater reductions in sales of fillets, which savings will be passed on to the consumer.

Judging from the above, this ceiling price of 3 cents a pound was based on data from 1942, which was, of course, *before* the substantial market for ocean pout was established in 1943 (p. 11); therefore 1942 was a period in which the demand for this species was extremely limited. The fish had not yet been "discovered," and the adoption of a ceiling based on 1942 prices was patently fallacious. The 3-cent ceiling had an immediate effect on the fishery. Some idea of the extent of the resultant drop in magnitude of the catch is apparent from a comparison of the 1944 figures for April with those of March in Tables I and II. But since the ocean pout landings have normally declined to a certain extent in April, a better indication of the extent of the reduction of this fishery by the 3-cent ceiling is afforded by a comparison of the receipts on the New York market in January 1944 (776,723 lb.) and January 1945 (66,446 lb.),¹ a drop to less than 10 per cent of the equivalent period in 1944.

As a result of this 3-cent ceiling price, therefore, a new fishery of considerable importance suffered drastic reduction in the spring of 1944 and in 1945. Quite apart from the consequent overall lowered fisheries productivity at a time when there was urgent need for increased landings, there were other adverse effects. As indicated earlier in this section (pp. 19-20), one of the chief obstacles in bringing about the full utilization of "trash" or little-marketed fish is reluctance on the part of the fishermen and other members of the industry to handle these species, either through prejudice or force of habit. Any added deterrent obviously magnifies the difficulties already inherent in the situation, not only with respect to the particular species concerned but also to other fish of potential value.

Communication with the Office of Price Administration in March 1945 established the propriety of the 3-cent ceiling on the basis of the 1943 open-market conditions at New Bedford where the average price received by fishermen was 3.1 cents per pound. Here again, however, the setting of a ceiling price on the basis of conditions in the *first year* of a fishery is at best a dubious procedure; not only is it likely to curtail the development of the fishery, but it also takes no account of

¹ Data from U. S. Fish and Wildlife Service Market News Service Monthly Summary, March 30, 1945.

possible increases in price as the species becomes better known and the demand rises. Some indication of the extent of the use of ocean pout in "tie-in sales" in 1944 was also provided by this Office, which showed that the average price paid to the fishermen in that year was 6.4 cents, a sum actually in excess of the average wholesale market price in New York. For example, in February 1944 ex-vessel prices averaged 9.1 cents per pound, while wholesale prices in New York City ranged from 1.5 to 8 cents per pound and averaged about 5 cents. Since wholesale prices normally include transportation and other costs as well as one wholesale mark-up, the conclusion was drawn that the legitimate price to fishermen could not have exceeded 3 cents per pound. Nevertheless, this price may have been unduly low. In February 1944, for instance, Massachusetts contributed 144,065 pounds to the New York market. This was only 10 per cent of the New Bedford catch in that month, and since a large proportion of the New Bedford ocean pout was filleted at the landing point, thus avoiding transportation costs and other mark-ups, the dealers there could well afford to pay a higher price to the fishermen. In other words, the estimate of what constituted a legitimate price to the fishermen in New Bedford on the basis of wholesale conditions in New York, when only a tenth or less of the New Bedford landings of ocean pout were shipped to New York and the majority were filleted¹ at the point of landing, may not have been reasonable.

Let us now turn briefly to the more general question of the efficacy of price regulation in controlling fish prices. The difficulties involved are readily apparent from even the most cursory survey of the activities of the Office of Price Administration (1943 to 1945), which at-

¹ According to information received from the U. S. Fish and Wildlife Service office at New Bedford, the recovery in ocean pout fillets in commercial practice during February and March 1944 varied from 23 to 36.5 per cent (averaged 27.75 per cent) of the weight of the whole fish. Filleting for optimal recovery under laboratory conditions, we recovered 47.8 per cent in unskinned and untrimmed fillets in a sample of 23 fish ranging from 56 to 75 cm. in length, well over half of the recovered portion by weight coming from the region posterior to the anus. At New Bedford fresh and frozen fillets generally brought an average price of 16 to 17 cents per pound in February and March of 1944, although one company reported an average of 23 cents for fresh fillets in this period. The fresh fillets generally were shipped to the Boston, New York and Philadelphia markets. About half of the fillets were frozen and shipped to the Middle West, principally Chicago. Referring to the Service's fear of overcrowding the freezers with ocean pout (p. 29), it is interesting to note from the above the very considerable magnitude of the market for fresh fillets.

tempted to work out the problems in conference with the Office of the Coordinator of Fisheries. The relatively small variety of fish which the Office of Price Administration had managed to place under ceilings by the spring of 1945, the interminable number of revisions and amendments which were necessitated, and the resultant confusion—sometimes causing a lowered fisheries productivity—indicate some of the complications in the attempts to effect price control of fish.¹ From the consumer's point of view, the effects of price control have been discussed by Kahn (1944) and Werner (1944). Kahn attempted to analyze the result of the original Maximum Price Regulation 507 controlling fresh fish prices at retail, and came to the conclusion on the basis of data collected several weeks before and after the enforcement (or attempted enforcement) that “. . . MPR-507 was a successful venture of the OPA, but still an adventure.” He further pointed out that no conclusion was possible as to whether this regulation would continue to be salutary for production-consumer relations, and that in some instances, which were fortunately in the minority, the regula-

¹ Maximum Price Regulation 418 (July 7, 1943) established maximum prices for 48 kinds of fresh fish in the New England and West Coast areas in sales by producers and wholesalers. It also pointed to “. . . the highly fluctuating nature of the industry, its seasonal features and the high perishability of fish in general” as some of the obstacles in the matter of fish price control. MPR 439 (July 20, 1943) fixed maximum retail prices at which retailers might sell the same species listed in No. 418 by the following method: “Every retailer, in order to determine his maximum selling price . . . shall take the same cents per pound mark-up over net delivered cost, which he took on the most sales during the period July 5 to July 10, 1943, inclusive, for the same style and form of the species being priced.” MPR 364 (effective April 13, 1943) fixed the maximum prices at which processors and wholesalers might sell frozen fish and seafood. However, this regulation had to be reissued September 6, 1944, to include Amendments 1-20, by which time it covered 77 kinds of frozen fish and seafood. On December 13, 1944, MPR 507 (originally effective January 27, 1944) was redesignated Revised Maximum Price Regulation No. 507, which included six outstanding amendments and fixed new ceiling prices for 52 kinds of fresh and 86 kinds of frozen domestic and imported fish and sea food items for all retail stores, retail route sellers and wagon retailers. RMPR 507 established cents-per-pound mark-ups for frozen fish and seafood for the first time in place of the application to “net cost” of a stated percentage mark-up. Apart from the obvious merit of simplicity of operation, this revision was necessary in order to “. . . make available to consumers many low-cost fish items not heretofore released from storage because retailers felt that the use of the percentage mark-up returned an unsatisfactory margin on such items.” Finally, MPR 579 (effective March 9, 1945) provided a schedule of maximum prices for North Atlantic species of fresh (20 types) and frozen (22 types) fish and seafood for the various kinds of producers, processors and wholesalers.

tion actually *increased* the prices above the then existing market level. Werner compared the prices of 10 species of fish in the spring of 1942 with the prices of the same species in 1944, at which time five were controlled by MPR 418. These data indicated that although ceilings probably kept the price of certain species from skyrocketing in periods of scarcity, they also apparently had the effect of maintaining a high price in periods of abundance. Werner concluded that in the absence of some ceiling prices and a serious meat shortage, consumers might pay more for out-of-season fish, but that their *total annual expenditure would be less*. Werner also indicated some of the difficulties arising from price control, citing particularly the whiting. In this case the fishermen actually limited their landings of this fish when they did not get ceiling prices in the summer of 1944, stating that they would starve at the lower remuneration they were receiving. There were two adverse results: 1.) decreased landings at a time when more fish were needed, and 2.) higher prices to the consumer because, "When fishermen demand and get ex-vessel ceilings from primary wholesalers, each wholesaler along the way also demands his ceiling price." Thus not only did the action of the Office of Price Administration on the whiting partially defeat its own purpose, but it had the added effect of actually reducing the nation's fisheries productivity. Even granting that this was an exceptional case, and overlooking the somewhat negative conclusions of Kahn and Werner in their analyses of the effectiveness of price control in limited sections of the fisheries industries, it is evident that the Office of Price Administration encountered great difficulties in its attempt to regulate fish prices. We are in no position to evaluate the overall effect of the attempted price control of fish in the United States from 1943 to 1945, although it seems reasonable to suppose that it was beneficial, especially in the period of acute meat shortage in 1945. But it is abundantly clear that inadequate data was at hand to allow the Office of Price Administration to accomplish its tasks in the most effective manner.

In considering the specific effect of the enforcement of price control on the ocean pout, it is apparent at this writing that the 3-cent ceiling established on March 18, 1944 (p. 23), cut a newly-established and prolific fishery to a drastic degree.¹ The necessity of Amendment

¹ Receipts on the New York market in 1945 were: Jan., 66,446 lb., Feb., 4,400 lb.—embargo on ocean pout in New York effective in February. New Bedford landings in 1945 were: Jan., 12,500 lb., Feb., 79,400 lb., March, 126,600 lb. Provincetown

26 to MPR 418, including a ceiling of the current market price or 5 cents a pound (whichever was less) on previously uncontrolled species in order to curb the black-market practice of "tie-in sales" (p. 23) was obvious; however, it is probable that any form of price-control itself almost inevitably fosters black-market conditions and illegalities of one sort or another. But the further cut-back on ocean pout to 3 cents by Amendment 27 a week later appears to have been short-sighted in the extreme. Amendment 26 had sufficient teeth in it to accomplish its purpose, and Amendment 27 not only served no additional good cause but seriously damaged a fishery of considerable potentialities in time of a great need.

It is difficult to conceive of the reasoning behind the 3-cent ceiling on ocean pout—especially when we remember the variety of fish *not* under price control (fresh mackerel, scup, butterfish, *etc.*—MPR 579). It might have been a form of double insurance against the continued use of ocean pout in "tie-in sales," although this seems hardly possible in the light of all the restrictions listed in Amendment 26 as well as the fact that other non-controlled species beside ocean pout were used for the same illicit purpose. On the other hand, it might have been prompted by the desire to eliminate a species which presented preliminary difficulties in marketing owing to its associated parasites. In the latter case, if sufficient information were available to show that these problems were insurmountable, the action might be justifiable. But in the absence of such information the action would appear to reflect poor judgement on the part of the specialists and others who advised the Office of Price Administration.

Discussion. In February 1945 the majority of the information on which this paper is based was available.¹ At that time also it was obvious that the ocean pout fishery was fast declining, both because of the 3-cent ceiling and because of an embargo placed on this species in New York by federal and city public health officials. We felt that

landings in 1945 were: Feb., 48,000 lb., March, 170,500 lb., April, 120,000 lb., May, 122,000 lb. Data from U. S. Fish and Wildlife Service Market Service sheets (January landings at Provincetown not given).

¹ As a result of conferences of the National Research Council committee on Food Resources of Coastal Waters, as well as extensive discussion and correspondence, it was known widely that this study was in progress. The data on which our work is based were not consulted by U. S. Fish and Wildlife Service officials.

this was unfortunate for a variety of reasons. First, it seemed to us that judgment by the Office of Price Administration and other agencies had been precipitous in view of the lack of specific information at their disposal; this was understandable in the difficult period in which this fishery had its inception, but to us, none the less regrettable. Second, providing the market problems associated with the ocean pout can be overcome, the fishery has much to recommend it. We need only cite specifically its potential magnitude as indicated by its contribution in the war emergency period, the closer approach to the optimal utilization of North Atlantic marine resources of which it is a part, and the fact that the major landings are made in the winter and early spring months when the quantity and variety of fish are frequently at a relatively low level and the demand is at its height. However, communication with U. S. Fish and Wildlife Service officials revealed a difference of opinion; they did not concur in the desirability of encouraging the ocean pout fishery on several grounds. The first of these lay in the problems associated with its parasitization—*i. e.*, the undesirability of fostering a product which might occasionally reach the market in objectionable form. As already indicated, it was difficult to accept this viewpoint because the parasitological difficulties raised by the ocean pout received extremely limited study (Fischthal, 1944, and Sandholzer, *et al.*, 1945). This position was rendered more untenable since this was a time when the demand for increased fisheries productivity was urgent. Such a policy carried to its extreme in the 1930's might have precluded the development of the fishery for redfish (footnote, p. 16), a fish which initially presented somewhat similar parasitization problems. No one will deny the necessity for building on quality in the fisheries industries. But when there is good evidence that the marketing problems can be partially or wholly overcome, every effort should be directed at surmounting the obstacles involved; inadequate attention to the problems which arise early in the development of a new fishery can be critical, not only to the particular species concerned, but also in the multiplicity of ramifications that arise therefrom.

The second ground for the Service's unwillingness to take action on the ocean pout in February 1945 lay in its fear of overcrowding the frozen storage facilities, due in part to the failure of less well-known species (*e. g.*, ocean pout) to move readily to market—*i. e.*, the fear that blocking freezers with substantial quantities of relatively slow-

moving fish might prevent the distribution of greater quantities of more acceptable species. It need only be mentioned here that this viewpoint is extremely difficult to reconcile with the following statements appearing in the U. S. Fish and Wildlife Service Market News Service:

April 17, 1945 (p. 1): Because of the current shortage of other protein foods, demand for fish is exceptionally heavy, the Coordinator's office reports. Present landings are rapidly absorbed by the market and less than normal quantities are being frozen for storage.

May 14, 1945 (p. 4): Holdings of frozen fish in the United States dropped 70,000,000 pounds during the first three months of 1945 to the below normal total of 39,829,575 as of April 1, the Fish and Wildlife Service of the Department of the Interior reported May 11, 1945.

June 28, 1945 (p. 3): A severe shortage of fish next winter was predicted June 25 by the Fish and Wildlife Service of the Department of the Interior on the basis of current holdings of frozen fish, which on June 1 totaled only 40 million pounds or 25 per cent below average.

Similarly, the following excerpt from House Report No. 504 (79th Congress, 1st Session),¹ is not easy to reconcile with the above-stated point of view:

Special inducements should be given . . . to the fishing industry to increase the supply of fish as quick sources of protein food to supplement dwindling meat supplies.

It should be clear from the preceding account that the issues concerning the ocean pout were controversial. We feel that a potential fishery of considerable magnitude was reduced to a relatively insignificant level on the basis of inadequate information. We cannot believe that the position taken by those who contributed to the reduction of this fishery, whether by their action or inaction, was well founded. Particularly is this so when we recall the limited data on which conclusions were based—for example, what was *not* known about the life history, the microsporidian parasite and even its identity (p. 9) (Sandholzer, *et al.*, 1945), the geographical and seasonal incidence of infection over the commercially fished range of this fish, and innum-

¹ Food Shortages. Report of the Special Committee to Investigate Food shortages for the House of Representatives, 1945. May 1, 1945—Committed to the Committee of the Whole House on the state of the Union and ordered to be printed. U. S. Government Printing Office, Washington, 1945. P. 16. (Union Calendar No. 126).

able other factors.¹ If the present contribution plays some small part in rectifying existing conditions and in providing a more reasonable basis for judgment of the ocean pout fishery, either as a direct result of the information contained herein or indirectly because of research which follows, our efforts are justified.

Summary. Until recently the ocean pout (*Macrozoarces americanus*), although taken abundantly by commercial fishermen in the southern New England area from January to June, was generally discarded as a "trash" fish. However, this species suddenly attained prominent market status in 1943 when it was first marketed in fillet form. The landings amounted to over 10,000,000 pounds in two years.

There is considerable evidence that the stock of ocean pout is capable of making an even more notable contribution to the nation's fisheries productivity. Furthermore, any trend toward the greater use of trash species implies a closer approach to the rational utilization of marine resources. The factors which control the extent to which these resources are used are many and complicated, but it is clear that we have not even approached an overall optimal level of exploitation and that the fisheries industries have much to gain from progress in this direction. The diffusion of fishing effort over more species should not only relieve the drain on the primary stocks, but it should also place the economic security of those engaged in the industry on a less hazardous basis. Moreover, a wider assortment of quality fisheries products, coupled with increased awareness of the consuming public as to the *variety* that are available, should lead to the more favorable competition of these commodities with other foods.

Various attempts to control the ocean pout fishery were made by the Office of Price Administration. These culminated in a 3-cent ceiling which reduced the landings in 1945 to a relatively low level. There is good reason for thinking that the 3-cent ceiling was unduly low, and that its consequences were not adequately considered. It is also apparent that insufficient data were at hand to allow the Office of Price Administration to establish price controls on fish in the most effective

¹ It should not be necessary to add that combined and cooperative attack by federal, state and private organizations is essential to most efficient progress in fishery biology, and that the U. S. Fish and Wildlife Service should act as a clearing house for all sources of material that are pertinent to its specialties in dealing with restrictions and regulations which impinge on its sphere of activity.

manner—witness among other things the large number of species which were not placed under control in the war emergency period.

An added factor in the reduction of the landings of ocean pout in 1945 was the embargo placed on this species in New York by city and federal public health officials because of the marketing problems arising from its parasitization. Granting that ocean pout fillets present certain difficulties, it appears that the condemnation of this fish because of its parasites was based on extremely meagre information.

Discussion with U. S. Fish and Wildlife Service officials emphasized the controversial nature of the issues involved, but it did not alter the conclusion that judgment on the ocean pout fishery was precipitous and did not take into consideration all the available information. Providing that the marketing problems can be overcome, the fishery has much to recommend it. The present paper should provide a fairer basis of evaluation.

PRELIMINARY DISCUSSION OF THE FISH

LITERATURE

Early accounts. The earliest American account of the ocean pout was given by Peck (1804), who very accurately described its principal characters and pictured it in unmistakable fashion from specimens taken mainly in March and April on haddock grounds near the Piscataqua River, New Hampshire. He further added the following comments:

It feeds principally on echini and asteriae of several species. To collect its food, it is necessary that it should frequent rocky places, and to this it must be owing, that in the larger individuals, the ventral fins are entirely obliterated, except two small cicatrices; so that at first view they appear to be a species of *Anarhicas*. It is therefore from the younger fish only that the classical character can be determined. From the resemblance above mentioned it has probably obtained the name of Wolf, by which it is known to our fishermen. It is sometimes called Conger Eel. In the consistence of the muscles it is like the eel, and deprived of its head and skin, it is sometimes sold as such; but it is preferable to the eel, as it feeds on living food; whereas the eel feeds on carcasses. The largest I have seen was 31 inches in length.

Mitchill (1815), apparently unaware of Peck's (*loc. cit.*) account, also gave a description of one which was brought to the New York market. Storer (1839) elaborated on his predecessors' work and added:

This species, which is incorrectly called by our fishermen "*ling*," sometimes attains the size of three and a half feet. It is seldom met with in Boston market. When young, its flesh is very sweet and palatable; I have repeatedly had it upon my table.

DeKay (1842) employed the English name *Eel-pout* (used for *Zoarces viviparus*) and commented on the fact that he had noticed this fish on the New York market most abundantly in February and March, that it is caught on the coast with cod, affords a very savory food, and that "It is called, absurdly enough, by the fishermen, *Ling* and *Conger-eel*."

Holmes (1862), in his report on the Fishes of Maine, stated:

Early in the spring and first of summer, the fishermen sometimes take, in company with cod, this fish to which, from its general resemblance to the Conger Eel, they frequently give the name of *Conger Eel* and *Ling*. It is also caught at other seasons of the year, but not so often. It is much prized by some people as a savory fish. Its common length is from one foot and a half to two feet. Occasionally one is caught from three to four feet long, but those of that size are rare.

Goode (1884) gave a general account of the fish based on the statements of earlier authors and compared it with its European counterpart, *Zoarces viviparus*. He wrote:

The Mutton-fish, *Zoarces anguillaris*, called Congo Eel and Ling, and also Lamper Eel, especially by the Maine fishermen, is often seen near the shore north of Cape Cod, and in winter especially is frequently taken with hook and line from the wharves. This species occasionally attains the length of three feet and the weight of six or seven pounds.

He also spoke of the fish as one " . . . which, while possessing excellent qualities as a food-fish, is not generally eaten." However, "It is occasionally eaten by the Cape Ann fishermen, by whom it is known as the Mutton-fish, . . . and I can myself testify to the delicacy of its flavor."

Bean (1903) noted that, "It is rather common north of Cape Cod" and is a common resident of deep water in Massachusetts Bay, frequently approaching the shore; he also called attention to its prevalence in the region of Marthas Vineyard in the fall of the year, and off Sandy Hook, New York, where it was known as mutton-fish.¹

¹ Nichols and Breder (1926) state that in the vicinity of New York it is almost universally known as "Conger eel."

Modern accounts. Comparatively recent discussions of this fish, although relatively few, substantiate many of the earlier observations and add further interesting information. Clemens (1920) and Clemens and Clemens (1921) worked on the life history and abundance of ocean pout in the Bay of Fundy with the primary object of providing information relative to placing it on the market in Canada. Apparently war-time conditions and the need for increasing food sources at that time also served as a stimulus for these researches. Huntsman (1922), Bigelow and Welsh (1925), Bigelow and Schroeder (1936) and others supply additional data. Since these works are quoted and discussed in the following pages they need no amplification here.

COMMON NAMES

In glancing through the foregoing excerpts from earlier accounts it is apparent that the popular names are many and have frequently led to confusion. As pointed out previously (p. 11), the terms "conger eel" and "congo eel" are particularly unfortunate owing to the difficulty of ascertaining whether the reference is to *Macrozoarces americanus* or to the unrelated *Conger oceanicus*. Similarly, "ling" is sometimes used, and this presents the possibility of confusion with the hakes (*Urophycis*); even "lamper eel" is unfortunate because of its similarity to the name "lampreys" (Cyclostomata). Storer (1857) stated: "At Bras d'Or it [*M. americanus*] is frequently taken . . . , and is confounded by the fishermen with the Lamprey." Fishermen also refer to them as plain "eels," "rock eels," "sea eels," "yowlers," "lipsyfish," "mother-of-eels," or "snake-fish." Fortin (1865) gave "chat de mer" and "congre" as common names in Canada, but he pointed to their inaccuracy and possible confusion with "*Anarrhichas Lupus*" and "*Conger Vulgaris*." The English name "mutton-fish," used for the European *Z. viviparus*, is applied in certain coastal areas because of the supposed resemblance of its flesh to mutton. In fact, Clemens (1920) proposed that this name be used for market purposes in Canada. "Eelpout" has been used most commonly, and is unquestionably more appropriate and less confusing than any of the above-mentioned terms, but this name is also used occasionally for the burbot (*Lota lota*) in some regions, as pointed out by Goode (1884).

Early in 1943 an attempt was made by the Committee for Increased Utilization of Sea Food Resources under the sponsorship of the U. S.

Fish and Wildlife Service to adopt a standard popular nomenclature for relatively little known species which were expected to be landed and marketed in increasing quantities. The unanimous choice of this group was the name "ocean pout" because, as quoted from an abstract of a meeting held on February 1, 1943:¹ "The name eelpout was considered misleading since this species is not related to the eels. Dealers have found it difficult or impossible to market the species under any name including the term 'eel'." In the last two years the term "ocean pout" has received fairly wide and successful usage, although complete consistency with this recommendation has not been maintained, thus leading to difficulties in the tabulation and interpretation of data such as that found in the Market News Service of the U. S. Fish and Wildlife Service.

CHARACTERISTICS

Distinctive features. The combination of heavy head and tapering elongate body, pointed tail, continuous dorsal, anal and caudal fins, apparent gap in the dorsal near the caudal fin, heavy thick lips, blunt conical teeth and eyes placed high on the head are characters which eliminate all other species in its range (Bigelow and Welsh, 1925). For further details see section on Taxonomy.

Observed behavior. Relatively few observations have been made on the habits and characteristic behavior of ocean pout, the fullest account having been given by Willey and Huntsman (1921):

A muttonfish 45 cm. in length was kept in one of the flat tanks of the laboratory during the latter half of the season and proved to be quite hardy. It fed regularly on the fish and shell-fish given it, approaching from a distance of more than a foot to take food from the hand. The enormous thick lips were used more than the teeth for taking hold of the morsels and a strong inspiration of water carried the food in. Swallowing did not immediately follow the taking of food, but was preceded by a rather prolonged series of masticatory movements involving both mouth and throat, and in which the head was nodded vigorously by movements in the vertical plane, the downward ones being the more vigorous.

The enormous pectoral fins were used in slow backward and forward locomotion, each fin being kept in a vertical position and slightly folded with the convex side in the direction of movement. At rest each fin is held out from the body almost in the horizontal plane and against the bottom, with the dorsal part posteriorly placed and somewhat raised. Rapid swimming is

¹ Fishing Gazette, 60 (4): 67, April, 1943. See also Fishing Gazette, 60 (10): 43, October, 1943.

accomplished by undulatory movements of the posterior part of the trunk and tail; the pectoral fins being extended to the fullest extent and held horizontally with the dorsal edge in front, while the dorsal and anal fins are kept close to the body, at least anteriorly.

Touching the side of the trunk or tail resulted in the erection of the dorsal fin. After repeated stimulation the response became rather local, extending both forward and backward from the level of the point touched, but chiefly backward. At the same time the fin was bent toward the side stimulated.

Clemens and Clemens (1921) noted that specimens in captivity tended to remain coiled up in the deepest parts of the tank, but that they swam swiftly and powerfully when disturbed. It is also obvious from Fig. 8 that ocean pout apparently coil around the eggs after the general manner of related members of this group. White (1939) described the recovery of two medium-sized ocean pout as well as a mass of eggs from a fisherman's rubber boot which was taken in a flounder trawl in January 1931 in the Bay of Fundy at about 10 meters depth, the water temperature being 0° C., and these observations fit the characteristic reproductive pattern of blennioid fishes. Most of the 842 eggs had hatched in the pan of sea water in which they were placed before the boat returned to dock a few hours later; White observed the rapid shrinkage of the yolk sac and the forcing of the yolk into the abdomen in not more than 20 seconds after hatching, which is in sharp contrast to the slowness of this process in salmonid species.

Nichols and Breder (1926) made the following comment on the behavior of this species: "the break in the contour of the shore eel-pout's vertical fins just over the tail . . . is apparently a defense adaptation. We have had this in mind in taking one from a hook, and noticing how it coiled back on itself, jaggng the hand with these spines." We have had similar experiences in tagging and measuring live ocean pout; the fish undulated vigorously and powerfully throughout the entire body length, sometimes coiling around the wrist or hand with spines raised in such a manner as to prick so sharply that it was next to impossible to retain a hold.

The feeding habits of the ocean pout have been described by a number of authors, and full reference to these accounts is made in a subsequent section devoted to this subject.

DISTRIBUTION

Range in latitude. The general range of the ocean pout is usually given as the Atlantic coast of North America from the Straits of Belle

Isle and the Gulf of St. Lawrence southward to Delaware. Clemens and Clemens (1921) gave a complete table of the records of distribution of this species. Some authors have extended the southern limits to North Carolina, apparently on the basis of a statement by Smith (1907):

The claim of this fish to a place in the North Carolina fauna is based on 2 small specimens said to have been caught by Dr. Yarrow with hook and line from the wharf at Fort Macon in May, 1871. The species has been observed by no one else, and must be regarded as a rare straggler so far south, assuming there has been no error in identification.

Range in depth. It is apparent from early and later literature, as well as from our own experiences, that this bottom-dwelling fish ranges from shallow intertidal zones down to very considerable depths, the capture of a number of specimens in July 1931 in the basin of the Gulf of Maine at 90 fathoms being reported by Bigelow and Schroeder (1936). In the northern areas around the Bay of Fundy, Clemens (1920) pointed to their being close to shore during the summer, at which time they are generally taken at depths up to 15 fathoms and sometimes 30, with one specimen recorded from 50 fathoms in April. He also stated that young specimens may be taken around rocks which are uncovered at low tide. According to Bigelow and Welsh (1925), ocean pout are taken in Penobscot Bay and Northeast Harbor in one to three fathoms and this probably applies all along the coast of Maine east of Cape Elizabeth. To the south, however, the picture is somewhat different, and ocean pout are not generally found in such shallow water. Goode (1884) reported a specimen taken in Gloucester Harbor at eight fathoms. In Massachusetts Bay Bigelow and Welsh recorded none at depths less than 10 fathoms, and in general it would appear that the majority of the stock of ocean pout is to be found between 10 and 45 fathoms in middle and southern New England waters. All of the collections on which this paper is based were made within the 30-fathom contour, the majority of fish being caught in 15 to 25 fathoms, with excellent hauls in as little as 10 to 12 fathoms (Fig. 3).

Bottom. Generally speaking ocean pout are found on all types of bottom, although there is good evidence that they prefer rocky areas at least during the summer and fall months in southern New England (p. 41). As pointed out by Clemens (1920) they are taken on every type of bottom in Passamaquoddy Bay; Huntsman (1922), on the other hand, specifically stated that they were taken on hard bottom.

According to Bigelow and Welsh they are hardly ever taken on stony or sandy fishing grounds, but rather on the soft sticky mud in the deeper parts of Massachusetts Bay. These authors also reported taking them on rather sticky sand in Ipswich Bay, on broken bottom at the mouth of Casco Bay, and on pebbles and mud in Penobscot Bay. To the east they are commonly caught on stony and rocky ground. All our own observations confirm the fact that ocean pout are taken on all types of bottom, although there appear to be seasonal preferences (pp. 40-42).

SEASONAL ABUNDANCE AND MOVEMENTS

From their own observations, as well as the data of other workers, Bigelow and Welsh (1925) concluded that this species does not undertake coastwise migrations, but that there are irregular on and offshore movements which differ seasonally with respect to the geographical areas involved. They stated:

The eelpout, broadly speaking, is a resident fish wherever found, its only migrations taking the form of on and offshore movements, and even these are irregular. In the Bay of Fundy, Huntsman describes them as working inshore in spring, moving out again into deeper water in October or early November, and as absent from the estuaries from January to April. Their abundance in Penobscot Bay in midsummer suggests that some of them perform a similar on and offshore migration there. However, this probably does not apply to the coast south of Cape Elizabeth and certainly not to Massachusetts Bay, where as careful an observer as Goode (et al., 1884) long ago described them as coming most often into shoal water in winter. Probably the truth is that their presence or absence close inshore, in any particular locality and season, depends not only on the local supply of food but on temperature, for the upper 10 to 15 fathoms in the southern part of the Gulf [of Maine] as a whole may well be too warm for them in summer, and estuaries particularly subject to severe chilling too cold in winter.

Clemens and Clemens (1921) in their studies of this species in the Bay of Fundy came to the following conclusions:

The sexually mature muttonfish leave the St. Croix river and Passamaquoddy bay about the end of July, and the remainder probably have left by the end of October. The height of the outward migration therefore occurs at the period of highest temperature. The inward migration probably begins early in April, which is the time when the temperature of the water in the St. Croix river and Passamaquoddy bay goes above 0° C. Fertilization of the eggs probably occurs in September which is the period of highest bottom temperature. There is thus a coincidence between the temperature extremes and the

migration periods, but whether or not there is a causal relation it is impossible to decide at the present time.

Our own observations show that ocean pout are abundant on southern New England commercial fishing grounds during the winter and spring months, but absent in the summer and fall months when only an occasional stray is taken by the small draggers and trawlers which operate in these waters (Fig. 2, Tables I, II). Since there is absolutely no evidence to show that this is a species which engages in coastwise migrations¹ (and indeed considerable data to indicate that it does not, pp. 115, 167), it appears reasonable at first sight to suppose that when ocean pout disappear from the catch in this general area it is because they have moved further offshore. This would mean that the same general pattern of migration as that indicated above by Clemens and Clemens held true, the essential difference being a four-month lag in northern waters where the fish are present inshore from April through October.² Nichols and Breder (1926) in "The Marine Fishes of New York and Southern New England" substantiate this view when they say: "Permanent resident, abundant in fall and winter to the westward In Maine this fish comes close in to the shore and shallow water, more or less, in summer. In our region it is found in moderately deep water, with probably some inshore tendency in winter."

However, it should not be concluded that ocean pout necessarily move offshore into much deeper waters during the warmer months in southern New England just because they are absent from the trawl-net catch from June to December. Sampling fish populations and estimating abundance in any geographical area on the basis of the

¹ Some 54 ocean pout were tagged during the course of this study (Table V), but no returns were obtained. Standard celluloid discs connected by a nickel pin through the mid-dorsal musculature after the manner described by Merriman (1941) were used; however, this species is extremely difficult to handle alive, and an opercular or other type of tag might simplify matters somewhat—although not enough to make tagging or measuring live ocean pout anything but a tedious and harassing proposition!

² Another difference between northern and southern New England ocean pout is the fact that in northern waters the fish come into extremely shallow water close to shore (p. 37), whereas there is no evidence that this is so south of Cape Cod. However, Bigelow (1914) recorded the capture of a number of specimens in July from the Gulf of Maine (Mass. and southern Maine) approximately 8–10 miles off shore at depths from 22–30 fathoms with temperatures ranging from 41.3–44.4° F.

catch by one type of commercial gear has obvious limitations. For example, Clemens and Clemens (1921) concluded that ocean pout are apparently absent from Passamaquoddy Bay from January to April since they caught none on set lines in this area in the winter of 1918-1919. But, as pointed out by Bigelow and Welsh (1925), this species may be one which does not feed to any great extent during this period. At this time the adults, as is the habit among blennioid fishes, may devote themselves chiefly to the care of their developing offspring in these waters—a habit which may preclude extensive feeding. Or there may be a selectivity in their diet which would make their capture on hook and line unlikely. Good evidence that they are not wholly absent from this region in January is provided by White's (1939) capture of several specimens in a flounder trawl at 10 meters. Similarly in regard to the absence of ocean pout in the summer and fall from the southern New England ground on which small trawlers work, there is considerable evidence to show that these fish frequent rocky bottom at moderate depths in this season where trawl nets cannot operate successfully. Thus Smith (1898) stated that they are "Abundant in fall, off Gay Head and Cuttyhunk; caught while line fishing for cod, on rock bottom, . . ." And commercial fishermen have reported to us in careful interviews that Provincetown boats take some ocean pout in relatively shallow rocky areas in Cape Cod Bay (between the Cape Cod Canal and Plymouth) in the summer and fall, and that New Bedford vessels also take them at this season in or close to rocky areas southeast of Block Island near the 20-fathom contour. Furthermore, one of us was on board a small dragger out of Stonington, Connecticut, which took small numbers of ocean pout in August and September while working at approximately 20 fathoms as close as possible to a notoriously "bad" bottom off Block Island. It is thus clear that at least part of the ocean pout population in southern New England waters remain in the same general depth zone in which they are taken in winter and spring, but move into rocky areas where their capture by trawl nets is at best fortuitous. In the absence of more numerous captures at much greater depths off southern New England it seems unwise to assume that a marked offshore migration necessarily occurs. Further evidence on this matter is provided in subsequent sections (pp. 110, 115). The speculation that the preference for rock bottom at certain seasons is in part governed by the spawning habits of this species seems reasonable in view of knowledge of related forms.

Spawning occurs in October in the region under consideration (pp. 70-77), and the protection of the developing eggs quite probably continues through November and part of December, after which time the fish appear in the trawl-net catches. Finally, it is of some interest that the suddenness of their appearance indicates mass migrations and heavy schooling rather than individual movements. For example, boats fishing off Old Harbor, Block Island in middle and late December 1943 took few ocean pout—*i. e.*, usually less than a dozen per drag of an hour or more; but on December 30 and January 2, 1944, the boats averaged 10-15 barrels (200 lb. per barrel) per drag in exactly the same locality.¹

SIZE

Such standard references as Bigelow and Welsh (1925), Breder (1929) and Nichols and Breder (1926) state that while this fish is said to reach a length of $3\frac{1}{2}$ feet and a weight of 12 pounds, most of those caught are much smaller, the usual maximum being between $2\frac{1}{2}$ and 3 feet. The largest specimen encountered in the present work, during which over 2500 individuals were examined, was a male $38\frac{1}{2}$ inches (98 cm.) in total length which weighed $11\frac{3}{4}$ pounds (5321 g.). This fish was taken 8 miles NNW. of Racepoint Light near Provincetown, Massachusetts, by the commercial dragger "Viola D" on March 15, 1944. It was the only individual we have seen which exceeded three feet. In fact, it is readily apparent from Fig. 4 that relatively few ocean pout over $2\frac{1}{2}$ feet in length were taken during the investigation, and that most of the individuals at the upper size limits were males. This latter fact provides evidence for the suggestion that the males tend either to live longer or grow faster than the females, thus attaining a greater size. The grouping of the points in Fig. 4 also makes it clear that the great majority of the fish fell in the one-foot interval between 16 and 28 inches (40.6-71.1 cm.).

The length-weight curve shown in Fig. 4 is based on the collections of ocean pout over a full year so that the relationship represents as nearly as possible an average condition which is not severely biased by the state of the gonads. If, for instance, the fish had all been taken in October just before spawning, the size of the ovaries would have

¹ The nets used were modified otter trawls with mouth widths of 80-120 feet. One of us was on board one of the boats on January 2 and saw 60 barrels taken in five hauls; most of the other vessels fishing the area were interviewed for corroborative data.

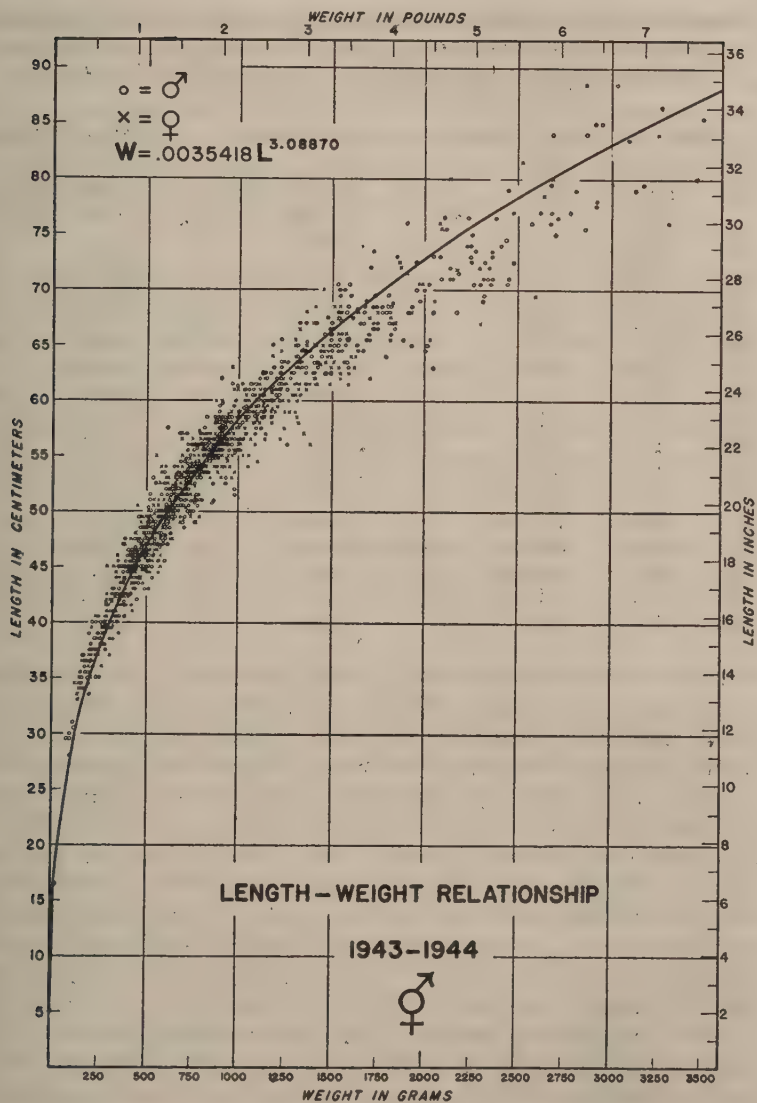


Figure 4. Regression curve showing the length-weight relationship of ocean pout of both sexes. Data based on 1114 individuals taken over a complete year from March 1943 to March 1944. See text for discussion; also Table III and Fig. 18. Not included in the figure, but used in the calculation of the formulae, were seven males (86 cm., 3629 g.; 88 cm., 3765, 3806, 4355 g.; 90 cm., 4241 g.; 91 cm., 3833 g.; 98 cm., 5321 g.) and one female (23 cm., 158 g.).

TABLE III. AVERAGE WEIGHTS OF OCEAN POUT FROM 25-100 CM. (10-39.5 IN.) IN LENGTH. DATA PRESENTED AT 5-CM. (2-IN.) INTERVALS FOR MALES, FEMALES, AND THE COMBINED SEXES IN GRAMS AND POUNDS. VALUES DERIVED FROM FORMULAE GIVEN IN FIG. 18.

Length Cm.	Males		Females		Males and Females combined	
	Nearest $\frac{1}{2}$ inch	Nearest 0.1 Gram	Nearest 0.1 Lb.	Nearest 0.1 Gram	Nearest 0.1 Lb.	Nearest 0.1 Gram 0.1 Lb.
25.....	10.0	66.6	1	81.4	2	73.6 2
30.....	12.0	119.5	3	139.2	3	129.3 3
35.....	14.0	195.9	4	219.3	5	208.2 5
40.....	16.0	300.6	7	324.9	7	314.4 7
45.....	17.5	438.7	1.0	459.8	1.0	452.4 1.0
50.....	19.5	615.1	1.4	627.1	1.4	626.4 1.4
55.....	21.5	835.2	1.8	830.4	1.8	840.8 1.8
60.....	23.5	1104.0	2.4	1049.0	2.3	1100.0 2.4
65.....	25.5	1427.0	3.2	1358.0	3.0	1409.0 3.1
70.....	27.5	1811.0	4.0	1690.0	3.7	1771.0 3.9
75.....	29.5	2259.0	5.0	2071.0	4.6	2191.0 4.8
80.....	31.5	2779.0	6.1	2505.0	5.5	2675.0 5.9
85.....	33.5	3376.0	7.4	2994.0	6.6	3226.0 7.1
90.....	35.5	4055.0	8.9	3543.0	7.8	3848.0 8.5
95.....	37.5	4823.0	10.6	4155.0	9.2	4548.0 10.0
100.....	39.5	5686.0	12.5	4833.0	10.7	5329.0 11.8

been such that the average weight of the individuals in the upper half of the curve (after sexual maturity has been attained) would have been considerably greater at each length interval. If, on the other hand, they had all been taken in January shortly after spawning, the average weight would have been less. It should be mentioned, however, that owing to the seasonal nature of the fishery by far the largest collections were made in the period from January to June, so that the values for the upper half of the curve are probably slightly less than they would have been if the sampling had been equivalent in each month of the year. A total of 598 males and 516 females were used in the preparation of the curve. The points plotted on the graph in Fig. 4 represent actual values and thus indicate in a general way the extent of the spread at the different length and weight intervals. The length-weight curve was fitted mathematically, the coefficient of regression being calculated by standard methods after Simpson and Roe (1939) to give the formula shown in the upper left corner of Fig. 4. Table III provides the average weights of ocean pout of each sex

separately and of males and females combined at 5-cm. (approximately 2-in.) intervals over the full range of size. It is of considerable interest that from 25–55 cm. the males tend to weigh less than the females and that above 50 cm. this relationship appears to be reversed. Further discussion of this point is presented in the section on age at maturity, where the male and female length-weight curves are also graphed (Fig. 18).

VITAMIN A ANALYSES

Analyses of two samples of ocean pout livers¹ were undertaken by the Research Laboratories of Distillation Products, Inc., Rochester, New York, through the kindness of Dr. K. C. D. Hickman and his staff.

It is well known that the Vitamin A potency of the livers of particular species of fish often varies over wide ranges. Brocklesby (1941) summarized some of the factors influencing these variations in Canadian fishes. Thus it has been shown that Vitamin A potency is related to size (the larger individuals yielding oil of higher value), color of the liver, season, etc. Templeman (1944) discussed the relation of the Vitamin A value of the oil from the livers of the spiny dogfish (*Squalus acanthias*) in relation to size, sex and degree of maturity. Any additional data obviously facilitates a clearer understanding and interpretation of the variations in Vitamin A potency of fish livers and also provides a better basis for establishing the fundamental principles which underlie its accumulation in animal tissues.

The first sample of ocean pout livers came from six fish taken on August 7, 1943, 15 miles SSE. of Point Judith, Rhode Island, at a depth of 20 fathoms. The size range of the fish was from 36 to 58.5 cm. (mean 50.0 cm.). The sexes were evenly divided—three males and three females. The livers were frozen and shipped from New Haven to Rochester packed in dry ice, where they were processed in their entirety. The per cent of oil by weight in these livers was 5.3, and the Vitamin A value 607 units per gram.

The second sample was composed of the livers from 27 ocean pout from a shipment of 100 specimens taken between June 15 and October 25, 1943, near St. Andrews, N. B., Canada. These fish were frozen as they were caught and shipped to New Haven for analysis in one lot in early November. The size range was from 28 to 54 cm. (mean

¹ The livers of ocean pout of marketable size average about 1.5 to 2.0 per cent of the weight of the whole fish.

43.5 cm.). The sexes were almost evenly divided—15 males and 12 females. The livers were refrozen, shipped and processed as was the first sample. The per cent of oil by weight in these livers was 0.7, and the Vitamin A value 16,500 units per gram.

If we now attempt to explain the differences in the livers of these samples, there are several matters to be taken into account. First, we should emphasize that the number of livers is extremely limited and that only two lots were tested. Furthermore, the difference in Vitamin A is not so great when considered in relation to the fat content, where a typical negative correlation exists, and variations of this magnitude are not uncommon in samples of this size. However, it is perhaps significant that we can eliminate a number of variables in comparing either the Vitamin A values or the fat content of these two samples. It seems evident that the differences are not attributable to the sex composition of the samples. It is also extremely unlikely that they were due to size or degree of maturity, since the differences between the two samples in these respects were not great, and especially since the sample from fish of *smaller* mean size had the higher Vitamin A potency. However, comparison of the feeding habits of ocean pout from the Bay of Fundy and southern New England (Table XII) does indicate certain differences which might possibly be significant. Thus in the northern fish, 18 per cent of the total volume of the stomach contents consisted of the remains of the green sea urchin, *Strongylocentrotus dröbrachiensis*, while in the fish from the Block Island Sound area this echinoderm was never present. Also, the Canadian fish showed a somewhat greater preference for a molluscan diet. It does not seem likely that these differences are sufficient to be of importance, but they cannot be excluded with certainty without further investigation. In regard to the physical environment,¹ the differences in depth and light between the two regions in which the fish were taken would not appear to be sufficient to warrant consideration; seasonal variations are also excluded. The most obvious factor is temperature, which on a year-round basis averages somewhat lower in Bay of Fundy waters than it does off southern New England. However, at depths of approximately 15 to 20 fathoms the differences between these two areas are usually only of the order of 3 to 5° C. (Bigelow, 1928). Speculation as to whether temperature differences of this sort could be significant in this

¹ Pugsley (1938) obtained no regularity of variation in Vitamin A potency of herring oils with respect to the locality of the catch in British Columbia.

regard is beyond the scope of this paper, but we wish to point out that this fish, by virtue of its size and general nature, is particularly well suited to study in aquaria or tanks and therefore to experimental approach on problems of the sort here indicated.

CLASSIFICATION, TAXONOMY AND OSTEOLOGY

GENUS *Macrozoarces* GILL, 1864.

Macrozoarces Gill, Proc. Acad. Nat. Sci. Philad. (1863), 1864: 256-258; type, *Enchelyopus anguillaris* (Peck, 1804).¹

When Gill concluded that Gronovius *Enchelyopus* had priority over, and with about the same limits as, *Zoarces* Cuvier, 1829, he created the subgenus *Macrozoarces* on the basis of the American form's larger head, much larger mouth, greater extent of the spinous portion of the dorsal fin, and the much larger number of caudal vertebrae compared with the European *Zoarces*. Jordan (1919: 325) subsequently raised *Macrozoarces* to generic rank. Most of Gill's generic differences may be questionable, but we believe there is ample justification for the separation of the two genera, particularly on the basis of the greater number of vertebrae in *Macrozoarces* (131-144), a correspondingly higher number of dorsal and anal fin rays and double rows of teeth in the front of both jaws (single in *viviparus*); furthermore, *Macrozoarces* is oviparous and attains a much larger size. Note, however, that this comparison is limited to a consideration of species in the North Atlantic only; species of the Pacific, and possibly elsewhere, now classified under *Zoarces*, have not been observed by us.

Generic characters. Head broad and heavy; body elongate and ensiform, tapering to a pointed tail; scales small and imbedded; lateral line arched anteriorly; lips large and fleshy; nares single; mouth large; upper jaw longer than lower; eyes high on head, more oval than round, and closely approximate; interorbital space narrow; teeth obtusely conical in both jaws, often worn and flat; branchiostegals 6; gills 4; rakers short, blunt and heavy, some with small terminal teeth; 4 to 6 on upper arch, 11 to 13 on lower; no palatine teeth; pharyngeal teeth stout, conical, some worn; vertebrae 131 to 144; dorsal, anal and caudal

¹ We regard Gill's type, *Enchelyopus anguillaris*, as a synonym of *Macrozoarces americanus* (Bloch and Schneider, 1801); likewise *Blennius anguillaris*, which Jordan (1919: 325) designated as the type for the genus *Macrozoarces*.

fins continuous; dorsal continuous from head to tail, of soft rays except for short series of spines in posterior part; anal fin continuous to tail, of soft rays only; ventrals small, of 3 multifurcate rays; pectorals broad and rounded, 18 to 21 rays; caudal very small and pointed.

Macrozoarces americanus (BLOCH AND SCHNEIDER), 1801

OCEAN POUT

Figure I

Remarks on nomenclature. In spite of the fact that Bloch and Schneider were quite vague in their description, all indications point strongly to the acceptance of *Blennius americanus* as having priority over *Blennius anguillaris* Peck, 1804. The strongest argument for its acceptance is to be found in the fact that Bloch and Schneider listed *americanus* immediately after the European form, *viviparus*, in their genus *Blennius* ("Pinnae ventrales didactylae, dorsalis mutica vel partim aculeata"). They must have been well acquainted with *viviparus* and unquestionably noticed the similarity of the American form ("Habitat in mari Americano"). Furthermore, in considering their systematic arrangement it seems unlikely that they confounded the American ocean pout with other closely- or remotely-related species, especially as regards the ventrals and the continuous anal, caudal and dorsal fins. Both *Muraena* (a true eel without ventrals) and *Trichiurus* (likewise without ventrals) are placed in entirely different classes; *Anarrhichas*, which has neither ventrals nor pointed tail, and *Ophidium*, with which confusion was possible because of the barbel-like ventrals, are in still another class, well removed from *Blennius*; the brotulid *barbatus* was placed in their genus *Enchelyopus*. It is also unlikely that they were describing a specimen of *Cryptacanthodes*, which has no ventrals. That they had a blenniod fish seems quite apparent; blennies were available to them, and it is improbable that they were considering a true blenny as restricted today. It is conceivable that another zoarcid or lycodid was being described by these workers, but when we consider the relative abundance and availability of the ocean pout as compared to other species in these groups, and when we note the position of *americanus* next to *viviparus*, this seems to be a very remote possibility.

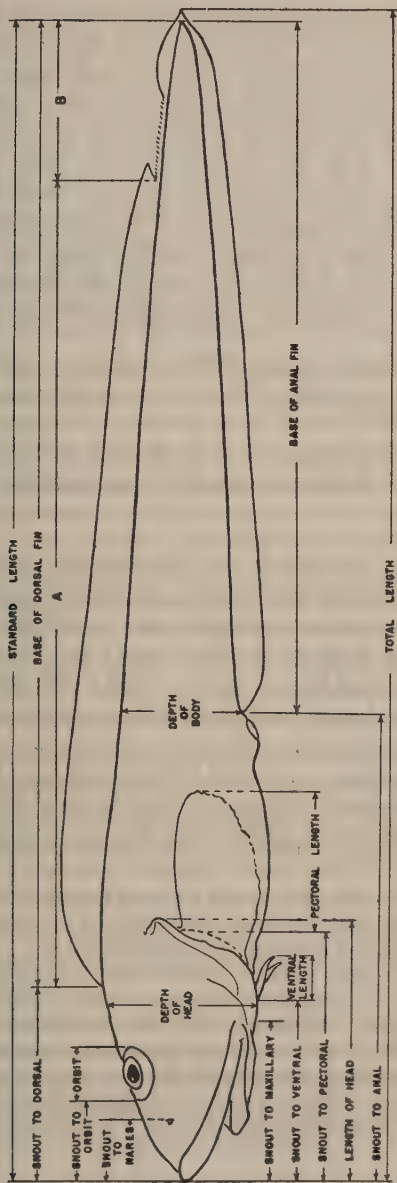


Figure 5. Illustration showing the extent and position of measurements made on the ocean pout. Specimens below 26 cm. in length were measured with dividers on a direct line (e.g., head measurements taken from tip of upper lip to opercular flap—not between the verticals from these points). Above 26 cm. all measurements were made with dividers except for the following measurements taken on the measuring board: T. L., S. L., base of dorsal fin, base of anal fin and snout to anal. Except for the three smallest specimens, the following head measurements were made with skin removed from eye region and posterior part of maxillary: interorbital width, eye, snout to orbit and snout to maxillary.

Following Bloch and Schneider's binomial account,¹ the ocean pout was clearly described by Peck (1804: 52, pl. 2, fig. 3) as *Blennius anguillaris*; this specific name has been most commonly used. Mitchill (1815: 374, 375) gave two descriptions, *B. ciliatus* and *B. labrosus*, and Cuvier (1829: 240) included Mitchill's *labrosus* in his newly-created genus *Zoarces*. Cuvier and Valenciennes (1836: 468, 471) gave Mitchill's *ciliatus* the new name of *Z. fimbriatus* and at the same time gave Gronovius' polynomial description of 1763 a binomial name, *Z. Gronovii*. Gill (1864) unwisely proposed that the American species be named *M. labrosus*. Jordan (1919: 325) designated *Blennius anguillaris* Peck, 1804 as the type for the genus *Macrozoarces* Gill, 1864.

Study material. Sixty-one females, 7.2 to 86 cm., and 61 males, 15.9 to 93 cm., from northern Cape Cod and southern New England.

Range. Western North Atlantic, from Straits of Belle Isle and Gulf of St. Lawrence to Delaware; possibly, but unlikely, to North Carolina.

Distinctive characters. The heavy head, the tapering elongate body, the pointed tail, the continuous dorsal, anal and caudal fins, the spinous portion near the tail in the predominantly soft dorsal fin, the heavy thick lips, and the eyes high on the head serve to distinguish this species from other western Atlantic fishes. It is easily distinguished from the true eels by the heavy head and the presence of small jugular

¹ A description by Gronovius (1763, no. 266: 77, "Enchelyopus subfuscus unicolor: pinna dorsi ad caudam integerrima . . . Habitat in Mari Americano") has been considered as applicable to the American ocean pout by some earlier workers. Also, Walbaum (1792: 185, 186) gave a description which has been included in the accounts of the American ocean pout ("Blennius, *unicolor*, pinna dorsi, ani, caudaeque unitis. W.").

According to Article 25 of the International Rules of Zoological Nomenclature (Schenk and McMasters, 1936: 32) "The valid name of a genus or species can be only that name under which it was first designated on the condition: a) . . . b) That the author has applied the principles of binary nomenclature." Therefore, the names of Gronovius and Walbaum, since they are not binary or binomial, have no priority over Bloch and Schneider, 1801. Referring in particular to Gronow, 1763, Opinion 89 stated, "Under suspension of the rules, in any case where such suspension may be considered necessary according to the interpretation now or hereafter adopted by the Commission, the following works or papers are declared eliminated from consideration as respects their systematic names as of their respective dates: Gronow, 1763; . . ."

ventral fins; from the blennies in that it has soft rays in the dorsal fin except for a small spinous portion posteriorly; from wrymouths by the ventral fins as well as the predominantly soft rays of the dorsal; from the wolffish by a more slender body, ventral fins, smaller teeth and pointed tail; from *Lycenchelys verrillii*, *Lycodes reticulatus* and *Lepophidium cervinum* by the posterior spinous portion of the dorsal fin. Comparing specimens of approximately the same size, it is separable from the *Zoarces viviparus* (Linnaeus)¹ of Europe by the slightly shorter head, the somewhat less heavy and more elongate body, the double rows of teeth in the front of both jaws (single in *viviparus*), greater number of vertebrae, the longer spinous portion of dorsal, and a dark spot about the size of the eye on the anterior part of the dorsal fin.

Description. Specimens 30 to 94 cm. long (see p. 55 for description and measurements of specimens 7.4 to 29.5 cm.). Body elongate and somewhat ensiform, tapering posteriorly from the broad, heavy head to a pointed tail; slightly compressed, more so posteriorly; dorsal and ventral profiles uniform and smooth; abdominal region tumid, very soft in fresh specimens, slightly shorter than head, about 14.8 to 20.4% (difference between measurements of head-length and snout-to-anus; Fig. 5); depth of body immediately posterior to anus, 8.9 to 12.9%.

Entire fish smooth. SKIN very tenacious and strong, covered with numerous small, white, cup-like depressions irregularly spaced. SCALES small, ovoid, separate, imbedded. LATERAL LINE of many small white pores, irregular in both shape and spacing, more distinct in preserved than in fresh specimens; commences above and anterior to posterior angle of operculum, proceeds for a short distance on a more or less straight line posteriorly, arches downward abruptly, levels off and continues on straight line to caudal; about 160 pores to point just anterior to spinous portion of dorsal. ANUS (with small urino-genital aperture on posterior margin) large, situated immediately anterior to anal fin. PORES visible on snout anterior, posterior and ventral to nares, below and posterior to eyes, on opercle and preopercle, on top of head anterior to dorsal and along body above lateral line to mid-body at least.

HEAD broader and heavier than body, length 15.6 to 24.6% in standard length, increasing in relative length with age, more so in males than in females (Table IV A and B, Fig. 6); depth 9.0 to 12.9%, in-

¹ We wish to express our appreciation to Leonard P. Schultz of the U. S. National Museum for the loan of a number of specimens.

creasing in relative depth with age; broad postero-ventrally, diminishing in width dorsally and anteriorly; dorsal profile somewhat angular (less so in older specimens), sloping gently from beginning of dorsal to point above eyes, then declining more abruptly to tip of snout; lower profile gently convex. SNOUT semi-blunt, with very fleshy appearance; tip of snout to anterior part of orbit (skin removed) 4.3 to 8.6%. NARES single, tubular, the posterior part longer than that anterior, located on line between lower eye and tip of snout, slightly nearer eye than snout; tip of snout to anterior part of nares, 2.9 to 6.4%. MOUTH large and almost horizontal. UPPER JAW strong, much longer than lower jaw, sloping downward at anterior end; tip of snout to posterior end of maxillary (skin removed) 7.9 to 16.8%. Maxillary extends posteriorly behind orbit in older specimens. LOWER JAW shorter, included in upper and sloping ventrally in anterior portion. LIPS heavy, fleshy and thick, the upper fleshier and heavier than lower, and protruding beyond the lower so that anterior part of lower lip generally coincides with inner posterior part of upper lip; upper lip heavier anteriorly than on sides; lower lip heavier on sides than anteriorly; both lips protrude well beyond skeletal structures. TONGUE sizeable, broad and fleshy, smooth. CHEEKS muscular and convex. EYES high on head, more oval than round, relatively small, approximate in smaller specimens, but less so in larger ones; horizontal diameter of orbit (skin removed) 2.9 to 4.8%. INTERORBITAL SPACE relatively narrow, 0.8 to 1.9% (skin removed). BRANCHIAL MEMBRANE fleshy, continuous and broadly united to isthmus, aperture moderate. BRANCHIOSTEGAL RAYS 6. GILLS 4; rakers on lower arch, commencing at angle, short, blunt and heavy, about as wide as long, each one bearing some small obtusely conical teeth at terminal ends; toward end of arch they diminish in size, the last one or two very small relatively and without terminal teeth; rakers on upper arch more pointed, not so heavy as lower ones, without terminal teeth, each one slightly longer than basal width; upper arch with 4 to 6 rakers, lower arch with 11 to 13.

TEETH obtusely conical in both jaws, but often worn flat anteriorly from grinding food; size range wide, from very small to large, the small ones placed irregularly between older teeth, probably to serve as replacements; most anterior teeth in upper jaw large, but in lower jaw smaller; lateral ones in upper jaw smaller than the lateral ones in the lower; in both jaws teeth are more approximate anteriorly; all slope

inwardly except anterior lower teeth. The outer series in upper jaw continuous, extending posteriorly on each side to a point in advance of rear angle of mouth; 12 to 15 on each side; shorter row anteriorly behind longer row; 5 or 6 on each side. In the shorter lower jaw the continuous series consists of 11 or 12 teeth on each side; but unlike those of the upper jaw, the second row in front is anterior to the continuous series, with 5 or 6 on each side. The above pattern persists for the most part with minor variations in those specimens we have examined. No teeth on palate. PHARYNGEAL TEETH in upper throat stout, conical, some worn at end; all 3 series on each side curved rearward; most anterior single series with 9 teeth on a side, these diminishing in size toward outer extremities; second series double, longer, with about 8 teeth in front row and about 5 in rear row, the smaller ones at outer extremities as in first series; third series double also, about half as long as second series, the teeth in both rows small, about same size and smaller than those at outer extremities of other two series, 9 in front row and 6 in rear row. In lower throat double rows on each side, with from none to as many as 5 scattered teeth between the rows; teeth conical, and those in each row slightly curved toward the other row; teeth in innermost row generally about twice as large or larger than those in outermost row; 9 or 10 in inner row, about 9 to 12 in outer row.

FINS. Dorsal, anal and caudal confluent, enveloped in thick fleshy membrane. DORSAL commences on head and continues uninterrupted to caudal, with a low short spinous portion near posterior end; distance from tip of snout to beginning of dorsal (on a diagonal line) 12.7 to 20%; length along base of dorsal 82.1 to 91.0%;¹ rays generally higher anteriorly than posteriorly; first 2, 3 or 4 close together, those following much wider apart but gradually and uniformly becoming more approximate as vertebrae diminish in size posteriorly; few anterior rays simple, the rest bifurcate, except for short, sharp, posteriorly-curved spines near caudal; number of rays 132 to 147.² ANAL fin lower than

¹ Length along base of dorsal from beginning of fin to anterior part of spinous portion 68.6 to 76.2%; from beginning of spinous portion to caudal, 12.1 to 17.6%.

² It was impossible to count accurately the most posterior fin rays; therefore seven specimens were examined to determine the inter-relationship of rays to vertebrae. From two to four rays were present anterior to the first vertebra, after which there was one ray for each vertebra, with the exception of the penultimate, which supports no dorsal ray. Hence, a relatively accurate ray count may be obtained by merely adding one, two or three to the total vertebral counts. Since these range from 131

dorsal, commencing directly posterior to anus and continuing uninterrupted to caudal; snout to beginning of anal 30.9 to 40.7%; base of fin 59.4 to 68.7%; rays higher anteriorly than posteriorly; spacing attendant upon the diminishing size of vertebrae posteriorly; first two rays simple, the remainder bifurcate; estimated counts 109 to 124;¹ anal fin decreasing relatively in length with age concomitant to diminishing length of body and posterior part of dorsal. CAUDAL fin very small, pointed and continuous with posterior of dorsal and anal fins; 12 bifurcate rays, 3 of which emanate from the penultimate vertebra ventrally (Fig. 15, and description p. 62). PECTORAL fins large, broad, rounded and very fleshy, scalloped at extremities, the base under or immediately behind posterior edge of operculum, or both; snout to upper pectoral base 15.7 to 24.2%; fin length 8.9 to 13.5%; rays branched, 18 to 21, but most specimens with 19. VENTRALS short, small, jugular, situated anterior to vertical line from anteriormost dorsal ray; snout to ventral base 11.5 to 19.8%; fin length 2.6 to 4.2%; three rays, multifurcate, enveloped in fleshy sheath, unequal in length.

Color of Fresh Specimens. General overall color muddy yellow, with mottlings of darker gray or olive-green; top of head darker than body, grading to lighter hues on cheeks, which are variously mottled; white or light lavender, or both, below; lips dirty yellow; inside of mouth a light beige. Body colors range from white or pale lavender below in abdominal region through yellow or dirty salmon tints to olive-green dorsally, with darker patches along back extending onto dorsal fin; the white or lavender of abdomen also extends along either side of base of anal fin about $\frac{2}{3}$ its length; edge of anal fin lemon yellow or sometimes a muddy pink; dorsal fin generally darker than anal, edged with yellow, changing to darker olive-green at base; pectorals generally red or orange, varying from olive-green at base to yellow-orange or reddish in marginal areas; ventrals yellow or pink. Pupil deep blue; iris orange flecked with brown.

Bigelow and Welsh (1925) stated:

to 144, the dorsal count would be 132 to 147. In the seven specimens observed the number of rays anterior to the spinous portion ranged from 91 to 93, the spines from XVII to XXI.

¹As in the case of the dorsal, the anal ray counts are estimated from the vertebral counts. There is one ray for each vertebra beginning with the 21st to 23rd vertebra; no ray is supported by the antepenultimate vertebra. Therefore, with vertebral counts of 131 to 144, these, less 20, 21 or 22, give ray counts of 109 to 124.

Although this fish has usually been described as reddish brown mottled with olive, or as salmon colored, most of those we have seen caught—a fair number—have been of some shade of muddy yellow, paler or darker, some with brownish, some with salmon, and some with orange tinge, while a few have been pure olive green; and since fishermen usually describe them as 'yellow', this is evidently the prevailing hue in the offshore parts of the Gulf. Other eel-pouts that we have caught inshore along the coast of Maine, however, have shown yellow only on the margins of the fins, particularly the lower edge of the pectorals, the general ground tint of sides and back ranging from pale gray, sometimes with purplish tinge, to dull brown or dark dusky olive below as well as above.

The younger fish (7.4 to 29.5 cm.). By comparison with specimens over 30 cm. the younger ones are more elongate and slender; the head is shorter and noticeably less heavy (length 15.3 to 18.1%; depth 8.9 to 10.9%), the abdominal region is approximately the same but less tumid (length 14.1 to 19.6%) and the body length is proportionately greater but not so deep (depth posterior to anus, 8.7 to 10.8%). The snout is blunter, the lips not nearly so fleshy, the gill rakers very short, blunt and stubby, the teeth sharper and not worn as in older fish. The following measurements are relatively less than those of the older fish: tip of snout to anterior part of orbit 2.9 to 4.9%; snout to anterior part of nares 2.8 to 3.7%; snout to posterior end of maxillary 5.7 to 9.4%; interorbital space 0.24 to 1.06%; snout to beginning of dorsal fin 12.9 to 15.8%; snout to beginning of anal fin 30.8 to 37.2%; snout to upper base of pectoral 15.3 to 18.5%; snout to base of ventrals 11.9 to 15.9%. The following measurements are relatively greater: horizontal diameter of orbit 3.4 to 4.9%; base of dorsal fin 87.0 to 92.9%; base of anal fin 67.0 to 70.4%; length of ventrals 3.8 to 5.8%. The pectoral length is relatively the same, 9.9 to 13.2%.

Color of young ocean pout. We have seen no fresh specimens, but presumably the color pattern is somewhat similar to that of the older fish. In the preserved state (formalin 10%) they have a mottled appearance of light and dark brown on sides and back, with the suggestion of yellow-green on the dorsal fin, which also bears irregular blotches; a dark streak extends across the cheek from eye to postero-ventral edge of operculum; the anal is light in color, with a suggestion of yellow; belly, ventrals, pectorals and ventral part of head also light.

Perhaps one of the most distinctive characters of the young is a dark spot on the anterior part of the dorsal fin. This was first observed by

Goode and Bean (1880), who noted its size as being about equal to the diameter of the eye. They also stated that it disappears with age, before or after the fish has attained a length of nine inches, and that there is no trace of this in young *Z. viviparus*. In our specimens we have observed that this spot, although less prominent, was present in specimens up to 30 cm. (12 in.) at least.

Heterauxesis. Table IV and Fig. 6 show that there is a proportionately greater growth of the head with age (tachyauxesis) and a proportionately diminishing growth with age in the body region posterior to the anus (bradyauxesis), while in the abdominal region there appears to be no relative change with age (isauxesis). Furthermore, the heterauxesis is probably more pronounced in males than in females, although more data is necessary to show this point conclusively. Fig. 6 shows the plottings of the lengths of the head, trunk and anal fin base (equal to the body length posterior to the anus) expressed in per cent of the standard length. In *A* the points are widely scattered, indicating isauxesis in the belly region; the measurements on which these percentages are based were obtained by deducting the head-length from the snout-to-anal-fin measurement. *B* shows tachyauxesis in the head region; although the points are scattered, a distinct trend is apparent. In *C* a similar trend is seen for the body region, but in this case the lengths diminish as the fish grows older (Needham 1942, Thompson 1942).

Osteology. Gregory (1933: 375) described the skull of *M. americanus* as follows:

Even in the highly specialized *Zoarces anguillaris* (Figure 253) the skull retains most of the familiar landmarks. Apparently this is a predacious, eel-like form with narrow skull and fairly large biting teeth in the front of the jaws. The hyomandibular is much enlarged and forms a firm pivot for the jaws. The preopercular is closely appressed to the hyomandibular and the back of the quadrate. The upper part of the small triangular opercular is sharply truncated, perhaps to make room for muscles running obliquely above it.

In the top view of the skull (Figure 254) we note the relative length and narrowness of the braincase, the large orbits and much constricted interorbital bridge, the relatively heavy muzzle formed by the stout prefrontals (parethmoids) and elongate mesethmoid, which widens in front, bearing a socket for the relatively strong ascending processes of the premaxillae.

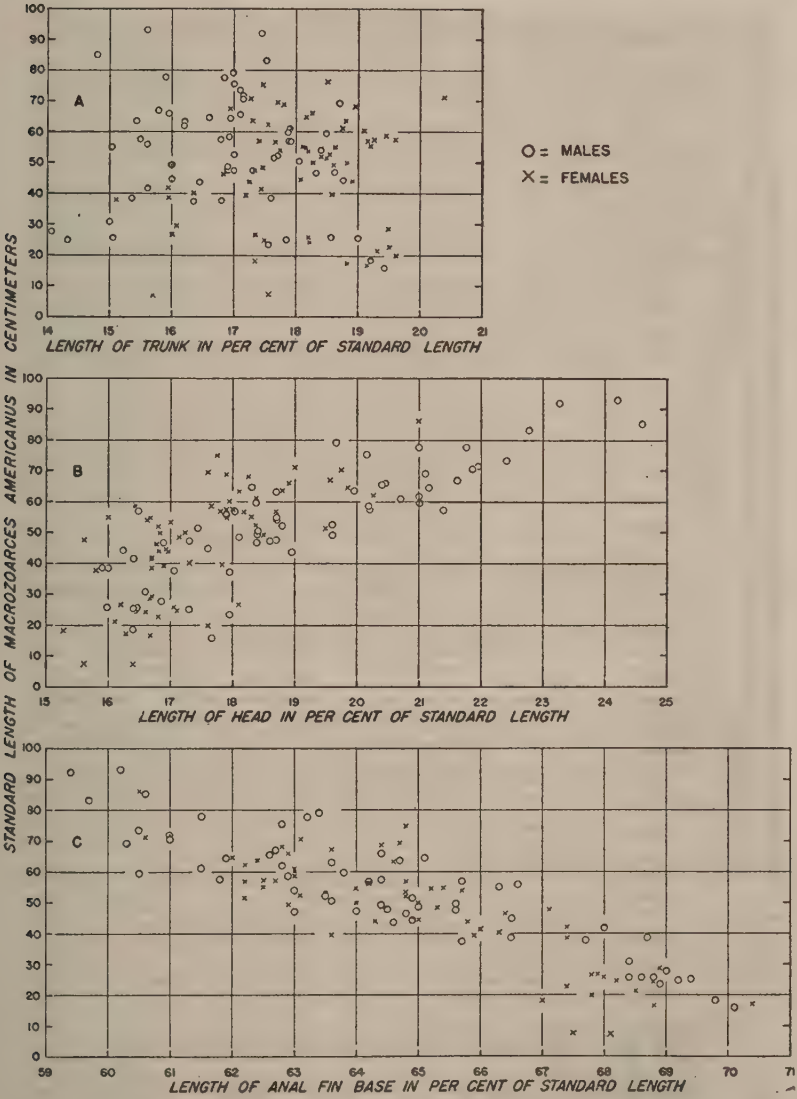


Figure 6. Heterauxesis in the ocean pout demonstrated by plotting the lengths of trunk (A), head (B) and anal fin-base or body (C) in per cent of the standard length (abscissae) against the standard length of the fish (ordinates) for both males and females.

TABLE IVA. MEASUREMENTS OF FEMALE OCEAN POUT IN PER CENT OF THE STANDARD LENGTH

Total Length (cm)	Standard Length (cm)	Total Weight (gm)	Head Measurements										Body Measurements								
			Length	Depth	Inter-orbital	Orbit	Snout to Orbit	Snout to Maxillary	Snout to Nares	Snout to Dorsal	Snout to Ventral	Depth	(Base of Dorsal Fin)			Base of Anal	Length of Ventral	Length of Pectoral	Snout to Anal	Snout to Pectoral	Trunk
7.4	7.2	...	16.4	9.6	0.42	4.0	2.9	6.3	..	13.8	12.4	8.8	67.2	20.1	87.3	68.1	5.8	13.2	32.1	16.7	15.7
7.8	7.7	...	15.6	9.4	0.39	4.9	2.9	5.7	..	13.3	12.6	..	..	..	87.0	67.8	5.2	11.9	33.2	16.5	17.6
16.6	16.5	25	16.6	9.6	0.24	3.6	4.3	7.9	3.3	14.1	12.6	9.6	74.9	17.6	92.5	68.5	4.4	11.6	35.8	15.3	19.1
17.3	17.2	26	16.3	9.9	0.41	3.7	3.8	7.0	3.5	13.8	12.3	10.8	74.3	18.6	92.9	70.4	4.5	12.3	35.1	16.3	18.8
18.3	18.1	...	15.3	10.5	0.72	3.9	4.2	6.7	2.8	14.3	12.2	10.0	69.2	18.1	87.3	67.8	3.8	10.8	32.6	15.3	17.3
20.0	19.9	36	17.6	10.1	0.50	4.5	4.8	8.0	3.4	15.1	14.2	9.5	71.3	17.1	88.4	67.8	..	11.3	37.2	17.9	19.6
21.3	21.2	44	16.1	9.2	0.52	4.2	4.2	7.6	2.8	13.3	13.0	8.9	72.7	18.4	91.1	68.5	4.3	..	35.4	16.1	19.3
22.7	22.6	63	16.8	9.7	0.80	4.2	4.0	8.3	..	15.4	14.8	10.0	73.9	16.8	90.7	67.4	4.9	11.5	36.3	17.3	19.5
24.2	24.1	70	16.6	9.8	0.75	3.9	4.4	8.3	3.4	13.8	13.8	9.1	72.2	17.6	89.8	68.8	4.6	11.2	34.8	17.3	18.2
24.7	24.6	72	17.1	10.0	0.81	3.9	4.3	7.9	..	14.2	14.4	9.8	73.5	17.3	90.8	68.2	4.5	10.6	34.6	17.5	17.5
25.9	25.8	83	17.1	9.7	0.85	3.9	4.6	8.1	3.4	14.3	12.5	10.1	73.6	17.8	91.4	68.0	4.3	9.9	35.3	16.5	18.2
26.6	26.4	80	16.2	9.1	0.83	3.8	4.5	7.5	..	12.9	12.5	9.8	74.3	17.1	91.4	67.8	3.9	10.3	32.2	16.9	16.0
26.7	26.5	102	18.1	10.6	1.06	4.3	5.1	9.4	3.7	15.8	13.6	10.2	75.8	14.7	90.5	67.9	4.5	10.9	35.5	18.5	17.4
28.7	28.5	120	16.7	10.2	0.77	3.5	4.2	8.2	..	13.8	13.3	10.2	75.0	16.1	91.1	68.9	4.3	11.7	36.2	16.9	19.5
29.5	29.3	104	16.7	8.9	0.85	3.4	4.9	7.9	..	14.0	12.7	8.8	74.5	16.0	90.5	..	..	..	32.8	16.5	16.1
38.3	37.9	218	15.8	9.5	0.85	3.2	4.7	7.9	..	12.7	13.3	9.3	75.2	15.6	90.8	..	3.6	10.2	30.9	16.7	15.1
38.6	38.3	317	16.7	9.9	1.31	3.5	5.2	8.1	3.5	14.1	13.1	11.7	75.2	14.9	90.1	67.4	..	10.6	32.7	16.5	16.0
39.7	39.3	343	16.9	9.4	1.07	3.4	4.9	9.0	2.9	14.0	14.2	11.2	73.8	15.8	89.6	65.9	4.1	11.4	34.1	17.2	17.2
40.2	39.8	360	17.8	11.3	1.06	3.4	4.5	8.6	2.9	13.8	13.9	11.3	73.6	15.8	89.4	63.6	3.8	11.3	36.4	17.8	18.6
40.5	40.1	325	17.3	9.8	1.24	3.3	4.7	..	3.1	14.2	13.7	10.7	74.8	15.2	90.0	66.3	4.0	12.0	33.7	17.4	16.4
41.8	41.4	387	16.7	10.6	1.18	3.4	5.0	8.8	3.3	14.3	11.8	11.2	74.5	14.7	89.2	66.0	3.4	10.7	34.1	16.7	17.4
42.3	42.0	367	16.7	9.7	1.12	3.4	5.1	8.6	..	13.5	12.4	10.5	73.8	14.5	88.3	67.4	3.7	10.9	32.6	16.6	15.9
44.3	43.9	444	17.0	10.2	1.14	3.2	5.3	8.4	3.5	14.8	12.8	10.9	75.2	13.7	88.9	65.8	3.4	10.7	34.2	17.1	17.2
44.3	44.0	506	16.8	11.0	1.02	3.2	5.0	8.6	3.4	14.1	13.7	11.8	73.3	16.8	89.8	64.3	3.4	10.6	35.7	17.3	18.9
44.7	44.3	502	16.9	10.4	1.02	3.0	5.0	8.6	3.2	14.1	13.3	11.4	73.3	15.4	88.7	65.0	3.4	9.9	35.0	17.4	18.1
46.4	46.2	590	16.8	10.1	1.04	3.2	5.0	8.6	..	14.1	13.5	11.9	74.0	15.6	89.6	66.4	3.3	11.9	33.6	15.9	16.8
48.1	47.7	506	15.6	9.4	1.01	3.6	4.7	8.4	..	13.4	11.6	9.8	75.3	15.1	90.4	67.1	3.7	10.0	33.0	15.7	17.3
48.7	48.2	666	17.1	10.0	1.24	3.1	5.4	9.0	3.4	14.3	13.5	11.1	73.6	15.3	88.9	65.3	3.5	10.4	34.6	17.2	17.5
49.7	49.3	746	18.5	11.2	1.20	3.6	5.9	9.9	4.3	14.5	15.0	11.2	74.0	15.2	89.2	62.9	3.6	12.5	37.1	18.7	18.6
50.3	49.9	720	17.2	9.7	1.00	3.1	5.2	9.3	3.3	14.4	13.4	11.4	74.6	14.8	89.4	64.0	4.0	11.2	36.1	16.9	18.8
50.3	49.9	785	16.8	10.7	1.24	3.0	5.0	8.3	3.5	13.5	13.6	11.2	74.2	14.8	89.0	65.0	3.6	11.2	35.1	16.6	18.3
51.9	51.4	870	19.5	11.7	0.99	3.6	5.7	10.3	3.7	15.6	13.6	10.9	74.5	13.8	88.3	62.2	3.7	11.9	38.0	18.3	18.5
52.5	52.0	785	16.8	10.6	1.21	3.2	5.2	8.9	3.7	14.3	13.5	10.6	73.0	15.6	88.6	64.8	3.3	10.6	35.2	16.9	18.4

TABLE IVA (cont.). MEASUREMENTS OF FEMALE OCEAN POUT IN PER CENT OF THE STANDARD LENGTH

Total Length (cm.)	Standard Length (cm.)	Total Weight (gm)	Head Measurements										Body Measurements									
			Length	Depth	Inter- orbital	Orbit	Snout to Orbit	Snout to Maxillary	Nares	Snout to Dorsal	Snout to Ventral	Depth	(Base of Dorsal Fin)			Base of Anal	Length of Ventral	Pectoral	Snout to Pectoral	Anal	Snout to Pectoral	Trunk
													A	B	A & B							
52.7	52.3	998	18.4	11.0	1.24	3.6	5.7	10.4	..	15.9	14.2	11.5	73.3	14.3	87.6	63.1	2.9	10.0	36.9	18.4	18.5	
54.0	53.5	814	17.0	10.8	1.20	2.9	5.2	9.3	3.9	14.8	12.1	10.5	72.5	15.7	88.2	64.8	3.4	10.0	35.2	16.7	18.2	
54.3	53.9	1043	16.6	11.3	1.10	3.0	5.4	8.5	..	13.8	12.4	11.5	75.8	14.1	89.9	65.7	3.3	10.4	34.4	16.7	17.7	
55.0	54.6	918	16.7	10.1	1.13	2.9	5.1	9.3	..	14.2	11.5	11.0	74.4	14.5	88.9	65.2	3.1	10.4	34.8	16.5	18.1	
55.1	54.7	1007	17.9	10.1	1.04	3.0	5.6	9.4	..	14.1	14.0	12.0	75.9	13.2	89.1	64.0	3.7	10.9	36.0	17.6	18.1	
55.2	54.9	1012	16.0	10.6	0.97	3.0	4.7	8.4	..	13.3	14.5	12.4	75.6	14.7	90.3	65.4	..	..	34.6	..	18.6	
55.5	55.2	1089	18.3	11.1	1.09	3.2	5.7	10.0	..	15.3	14.5	12.0	72.4	15.2	87.6	62.5	3.8	11.1	37.5	18.4	19.2	
56.8	56.4	1066	18.2	11.1	1.67	3.3	5.3	9.8	..	13.9	14.8	11.4	72.6	14.5	89.5	64.2	3.2	11.6	35.9	17.8	17.7	
57.2	56.8	1093	17.8	11.4	1.06	3.3	5.6	9.5	..	14.6	13.7	11.9	72.6	15.1	87.7	64.8	3.9	11.6	35.2	17.8	17.4	
57.2	56.8	1034	18.7	11.4	1.23	3.7	5.8	10.6	4.2	15.2	14.4	10.6	73.0	14.6	87.6	62.2	3.5	11.1	37.9	17.9	19.2	
57.6	57.2	1275	18.0	10.5	1.05	3.2	5.6	10.0	..	14.3	14.5	12.3	74.6	14.0	88.6	62.7	2.6	10.7	37.3	18.2	19.3	
57.8	57.3	868	17.9	10.2	1.17	3.4	5.6	9.6	4.0	15.0	14.0	9.4	72.7	15.4	88.1	62.5	2.9	10.3	37.5	18.3	19.6	
59.0	58.6	1302	17.7	10.7	1.20	3.1	5.1	9.7	3.2	14.0	14.2	12.1	73.5	14.7	88.2	63.0	3.1	..	37.1	16.9	19.5	
60.7	60.2	998	17.9	10.1	1.00	3.2	5.8	10.1	4.2	14.8	14.5	10.3	73.5	14.8	88.3	63.0	3.5	8.9	37.0	18.0	19.1	
61.4	61.0	1270	18.4	10.8	1.15	3.2	5.5	10.5	3.5	15.1	13.9	10.8	76.2	14.8	91.0	63.0	3.7	11.5	37.1	18.2	18.7	
62.7	62.2	1769	20.3	11.4	1.09	3.5	6.6	11.6	..	16.5	14.4	12.9	72.8	14.3	87.1	62.2	3.5	11.9	37.8	19.0	17.6	
64.0	63.6	1438	18.1	11.0	1.18	3.3	5.3	10.2	..	14.1	13.7	11.0	75.4	13.7	89.1	64.6	3.5	10.7	35.4	17.4	17.3	
64.2	63.8	1542	18.8	11.4	1.22	3.3	6.4	11.1	3.8	15.5	14.2	11.7	72.9	15.4	88.3	62.4	3.4	11.3	37.6	18.1	18.8	
64.9	64.5	1778	19.9	12.4	1.24	3.9	5.5	11.6	..	15.2	14.4	11.5	73.6	13.8	87.4	62.0	3.4	11.2	38.0	18.9	18.2	
66.5	66.0	1270	18.9	10.7	1.44	3.1	6.0	10.4	3.9	15.5	13.3	12.3	73.1	14.1	87.2	62.9	3.3	10.5	37.2	18.5	18.9	
67.6	67.2	1769	19.6	11.6	1.49	3.8	6.6	11.5	..	15.6	14.4	10.7	74.1	13.8	87.9	63.6	3.4	12.0	36.5	18.3	16.9	
68.5	68.1	2046	18.3	11.2	0.90	3.7	5.1	10.4	..	14.1	13.9	11.6	74.5	14.1	88.6	62.8	3.4	10.7	37.2	17.5	17.8	
69.0	68.7	1805	17.9	10.8	1.19	3.2	5.9	9.7	..	14.6	14.8	11.2	75.0	12.1	87.1	64.4	3.4	10.9	35.7	18.9	18.9	
69.8	69.5	1805	17.6	10.9	1.18	3.2	5.5	9.6	..	14.5	13.1	10.6	73.4	15.0	88.4	64.7	3.4	10.8	35.3	17.2	17.7	
70.8	70.4	1898	19.8	10.4	1.31	3.6	6.5	11.5	..	15.6	14.8	10.4	74.8	13.1	87.9	63.1	3.2	10.9	37.0	19.8	17.3	
71.7	71.1	2381	19.0	11.3	1.28	3.4	6.1	10.4	..	15.2	15.0	11.7	72.4	14.2	86.6	60.6	3.7	11.0	39.4	18.6	20.4	
75.7	75.2	2508	17.8	10.0	1.17	3.2	5.3	9.4	..	14.1	14.2	10.9	73.0	15.0	88.0	64.8	3.1	9.8	35.2	17.4	17.5	
86.9	86.2	4137	21.0	10.2	1.34	3.7	6.9	12.9	4.8	16.3	16.2	11.0	73.4	13.2	86.3	60.5	2.8	..	39.5	20.8	18.5	
7.4	7.2	25	15.3	9.1	0.24	2.9	2.9	5.7	2.8	12.7	11.5	8.8	67.2	12.1	86.6	60.5	2.6	8.9	30.9	15.3	15.1	
86.9	86.2	4137	21.0	12.4	1.49	4.9	6.9	12.9	4.8	16.5	16.2	12.9	76.2	20.1	92.9	70.4	5.8	13.2	39.5	20.8	20.4	

TABLE IVB. MEASUREMENTS OF MALE OCEAN POUT IN PER CENT OF THE STANDARD LENGTH

Total Length (cm)	Standard Length (cm)	Total Weight (gm)	Head Measurements										Body Measurements									
			Length	Depth	Inter- orbital	Orbit	Snout to Orbit	Snout to Maxillary	Snout to Nares	Snout to Dorsal	Snout to Ventral	Depth	(Base of Dorsal Fin)	A	B	A & B	Base of Anal	Length of Ventral	Length of Pectoral	Snout to Anal	Snout to Pectoral	Trunk
16.0	15.9	20	17.7	10.3	0.31	4.7	4.5	7.9	3.6	14.5	14.5	9.3	72.9	17.6	90.5	70.1	4.5	10.7	17.6	37.1	16.4	19.4
18.4	18.3	29	16.4	10.3	0.44	4.1	4.5	7.7	3.3	14.2	12.4	9.4	71.5	19.2	90.7	69.8	4.4	11.5	16.4	35.6	16.4	19.2
23.6	23.4	67	18.0	10.9	0.77	3.9	4.8	8.6	3.3	14.3	15.9	10.3	72.8	17.2	90.0	68.9	4.4	11.5	18.5	35.5	18.5	17.6
24.3	24.7	61	16.4	9.4	0.73	3.6	4.5	8.0	..	14.0	12.9	8.2	74.0	15.8	89.8	69.2	4.8	10.5	30.8	35.2	18.2	17.9
25.3	25.1	75	17.3	10.4	0.60	3.8	4.9	8.8	..	14.7	15.6	9.9	73.6	18.3	91.9	69.4	4.0	10.9	35.2	35.4	17.7	19.0
25.6	25.4	71	16.4	9.8	0.71	3.9	4.3	8.0	3.6	13.8	15.0	9.4	73.8	18.0	91.8	68.8	4.3	10.6	35.4	31.5	16.3	15.0
25.9	25.7	68	16.5	9.7	0.78	3.5	4.6	8.1	..	14.0	12.8	8.7	73.8	17.1	90.9	68.4	4.1	10.9	31.5	31.5	15.9	18.6
25.9	25.8	80	16.0	9.5	0.85	3.9	4.2	7.6	3.5	13.0	11.9	9.7	74.4	16.2	90.6	68.6	4.0	10.0	34.6	34.6	15.9	18.6
27.9	27.8	99	16.9	9.1	0.79	3.8	4.7	7.9	..	13.4	13.4	10.1	74.8	16.2	91.0	69.0	4.3	10.4	30.9	30.9	16.9	14.1
30.9	30.7	127	16.6	9.3	1.14	3.6	4.8	8.0	..	13.1	12.7	9.2	73.3	17.6	90.9	68.4	4.2	10.6	31.6	31.6	16.6	15.0
37.7	37.3	232	18.0	10.2	1.29	3.7	5.4	9.6	3.5	15.0	15.0	9.5	73.2	16.1	89.3	65.7	3.9	10.5	34.3	34.3	18.3	16.4
38.1	37.8	244	17.1	9.9	1.06	3.6	4.5	9.1	..	13.5	13.0	9.4	74.5	14.8	89.3	67.7	3.7	11.8	33.9	33.9	16.7	16.8
38.6	38.3	228	16.0	9.2	0.78	3.6	5.0	8.4	..	13.1	13.2	8.9	74.4	15.7	90.1	68.7	3.4	9.8	31.4	31.4	15.7	15.4
38.7	38.5	255	15.9	10.2	0.96	3.4	4.3	8.1	3.4	13.2	12.3	9.7	74.7	16.1	90.5	66.5	3.9	9.6	33.5	33.5	16.2	17.6
41.7	41.5	298	16.4	9.5	1.08	3.4	4.9	8.6	..	13.0	12.3	9.9	74.7	16.2	90.9	68.0	3.4	10.1	32.0	32.0	16.6	15.6
44.1	43.8	504	19.0	10.5	1.14	3.6	5.7	11.4	..	15.4	15.1	11.6	71.9	15.8	87.7	64.6	3.5	10.5	35.4	35.4	18.6	16.5
44.5	44.2	388	16.2	9.1	1.08	3.4	5.4	9.4	3.6	14.7	14.6	10.2	73.0	15.4	88.4	64.9	3.2	10.8	35.0	35.0	17.5	18.8
45.0	44.7	529	17.6	10.7	1.16	3.2	5.4	9.4	3.8	14.3	13.3	11.6	74.0	15.7	89.7	66.5	3.6	10.1	33.6	33.6	16.5	16.0
46.7	46.3	548	16.9	9.9	1.08	3.3	5.2	9.1	3.7	13.8	13.8	11.0	73.8	15.3	89.1	64.8	3.0	10.8	35.2	35.2	17.3	18.3
47.1	46.8	614	18.4	10.7	1.18	3.4	5.8	10.5	3.8	15.6	15.4	11.4	72.6	15.4	88.0	63.0	3.3	10.3	37.0	37.0	18.7	18.6
47.6	47.3	627	18.6	10.9	1.44	3.5	5.5	10.1	3.9	14.6	14.5	10.6	74.2	15.0	89.2	64.0	3.8	11.0	35.9	35.9	18.2	17.3
47.8	47.5	506	17.3	10.1	1.05	3.6	5.7	9.5	..	14.4	13.9	9.3	..	15.2	..	65.6	3.4	10.8	34.3	34.3	17.5	17.0
48.1	47.8	591	18.7	10.3	1.21	3.5	6.5	10.8	4.2	16.3	14.7	10.8	73.2	14.9	88.1	64.5	3.4	10.5	35.6	35.6	18.6	16.9
48.9	48.6	700	18.1	10.7	1.09	3.3	5.6	10.3	4.0	14.9	13.8	11.5	74.0	15.0	89.0	65.0	3.8	10.9	35.0	35.0	16.9	16.9
49.7	49.2	876	19.6	11.3	1.28	3.6	6.0	12.2	..	15.6	15.3	12.6	75.2	13.2	88.4	64.4	3.9	11.8	35.6	35.6	18.4	16.0
49.9	49.5	656	18.4	9.7	1.33	3.2	5.9	10.5	..	14.9	13.7	10.1	72.0	16.2	88.2	65.6	3.2	9.7	34.4	34.4	18.0	16.0
50.9	50.5	717	18.4	11.4	1.48	3.2	6.0	9.7	4.0	15.1	14.4	10.6	74.2	13.5	87.7	63.6	3.3	10.8	36.5	36.5	18.0	18.1
52.0	51.6	668	17.4	9.9	1.16	3.1	5.5	10.1	3.9	14.4	14.2	9.9	72.7	15.7	88.4	64.9	3.1	10.3	35.1	35.1	17.8	17.7
52.5	52.1	819	18.8	10.9	1.29	3.3	6.5	10.9	4.2	15.5	14.5	11.9	71.0	16.3	87.3	63.5	3.5	10.7	36.6	36.6	18.5	17.7
53.1	52.5	776	19.6	11.4	1.52	3.5	6.6	12.0	4.4	16.4	15.4	10.9	71.6	15.6	87.2	63.5	3.3	10.6	36.5	36.5	19.5	17.0
54.3	54.0	1025	18.7	10.5	1.39	3.2	6.2	11.5	..	15.6	14.8	11.7	73.7	13.9	87.6	63.0	3.3	10.7	37.1	37.1	18.9	18.4
55.3	54.9	1021	18.7	11.8	1.48	3.3	6.3	10.6	3.9	16.1	14.8	11.4	72.9	14.9	87.8	66.3	3.6	12.0	33.7	33.7	18.9	15.0
56.3	55.9	1075	17.9	10.3	1.07	3.1	6.1	10.2	..	15.1	14.6	11.4	71.8	..	..	..	3.6	10.3	33.5	33.5	17.8	15.6

TABLE IVB (cont.). MEASUREMENTS OF MALE OCEAN POUT IN PER CENT OF THE STANDARD LENGTH

Total Length (cm)	Standard Length (cm)	Total Weight (gm)	Head Measurements										Body Measurements								
			Length	Depth	Inter-orbital	Orbit	Snout to Orbit	Snout to Maxillary	Snout to Nares	Snout to Dorsal	Ventral	Depth	(Base of Dorsal Fin)			Anal	Length of Ventral	Length of Pectoral	Snout to Anal	Pectoral	Trunk
57.2	56.8	964	16.5	9.9	1.16	3.4	5.0	9.5	..	13.6	13.9	10.7	14.1	88.9	65.7	3.0	10.1	34.4	16.2	17.9	17.9
57.2	56.9	828	18.0	10.6	1.16	3.3	6.3	10.7	..	15.3	14.8	9.6	73.3	87.2	64.2	3.9	11.5	35.9	18.6	17.9	17.9
57.9	57.5	1111	20.2	11.7	1.48	3.5	6.7	12.0	..	16.4	15.7	11.3	73.7	87.6	64.4	3.7	11.3	35.7	19.8	15.5	15.5
57.9	57.6	1134	21.4	11.5	1.18	4.2	6.8	13.9	..	17.5	17.5	10.4	70.8	85.5	61.8	..	11.1	38.2	21.4	16.8	16.8
58.9	58.5	1196	20.2	11.1	1.01	..	6.6	12.7	..	16.4	14.9	11.2	70.0	84.5	62.9	3.6	10.9	37.1	20.3	16.9	16.9
59.9	59.5	1361	21.0	11.6	1.23	4.0	7.2	13.6	..	17.3	16.7	11.4	70.3	85.1	60.5	..	11.1	39.5	20.9	18.5	18.5
60.2	59.9	1311	18.4	11.3	1.42	3.0	6.1	11.3	4.0	15.4	15.4	12.0	72.6	87.5	63.8	3.6	11.2	36.3	18.3	17.9	17.9
61.3	60.9	1220	20.7	11.2	1.20	3.8	7.2	13.5	5.3	17.1	14.6	10.3	72.2	86.0	61.5	3.0	9.7	38.6	19.8	17.9	17.9
62.3	61.9	1538	21.0	11.9	1.13	3.7	7.4	14.4	..	17.1	17.0	11.1	72.3	87.2	62.8	3.5	10.3	37.2	20.9	16.2	16.2
63.5	63.1	1624	18.7	10.9	1.25	3.7	5.9	11.3	..	15.1	14.4	11.1	73.7	88.1	63.6	3.4	11.3	34.9	17.8	16.2	16.2
64.0	63.7	1383	19.9	11.1	1.33	3.8	6.3	11.5	..	15.8	15.9	10.2	72.4	87.0	64.7	3.3	11.6	35.4	19.6	15.4	15.4
64.8	64.3	1724	21.2	11.8	1.40	3.6	7.3	14.2	..	18.1	17.8	11.5	70.7	85.3	61.9	3.4	10.2	38.1	20.8	17.0	17.0
64.8	64.5	1270	18.3	10.6	1.32	3.4	5.9	10.7	..	15.1	14.3	10.1	72.3	87.7	65.1	3.3	11.1	34.9	18.7	16.6	16.6
65.8	65.4	1778	20.4	11.2	1.22	3.2	6.7	13.0	..	16.1	15.4	12.1	71.9	86.3	62.6	3.4	10.7	37.5	19.4	17.1	17.1
66.5	66.0	1506	20.5	10.6	1.38	3.7	6.2	12.4	..	17.1	15.4	10.8	72.0	86.2	64.4	3.6	11.1	36.4	20.2	16.0	16.0
67.3	66.9	1805	21.6	11.7	1.42	3.9	7.5	14.6	..	17.1	17.4	11.2	71.4	85.9	62.7	3.7	11.5	37.4	21.6	15.8	15.8
69.6	69.2	2059	21.1	11.7	1.17	4.1	7.2	14.1	..	17.5	16.5	11.0	71.2	85.7	60.3	3.6	11.6	39.8	20.6	18.7	18.7
71.0	70.5	1896	21.9	11.5	1.70	3.7	7.8	14.2	5.6	18.0	16.5	10.4	71.0	85.2	61.0	3.3	11.0	39.0	21.7	17.2	17.2
72.0	71.6	2223	22.0	12.0	1.33	4.1	8.2	15.6	5.5	18.7	18.6	11.7	70.2	84.7	60.9	3.4	10.3	39.1	23.1	17.2	17.2
73.9	73.4	2350	22.4	12.9	1.50	3.9	8.0	15.5	5.7	18.8	17.1	10.1	70.0	84.6	60.5	3.1	12.4	39.5	21.5	17.1	17.1
75.8	75.4	2304	20.2	11.4	1.51	3.8	6.8	13.4	..	16.2	16.8	10.1	72.7	86.0	62.8	3.5	11.4	37.2	20.1	17.0	17.0
78.2	77.8	2536	21.0	11.2	1.54	3.7	7.0	12.4	4.6	16.6	16.6	10.4	71.5	84.3	61.5	3.3	..	36.9	20.2	15.9	15.9
78.2	77.8	2486	21.8	11.7	1.44	3.8	7.6	14.3	4.8	17.4	18.7	10.4	69.8	84.2	61.5	2.7	9.9	38.6	22.1	16.9	16.9
79.6	79.1	2877	19.7	10.6	1.39	3.5	6.7	13.0	..	16.5	15.5	10.6	72.0	86.0	63.4	3.4	11.6	36.7	19.2	17.0	17.0
83.6	83.1	3402	22.8	12.0	1.77	4.2	7.5	16.3	5.2	18.1	19.8	9.9	71.6	84.4	59.7	3.9	12.4	40.3	23.1	17.5	17.5
85.6	85.1	4364	24.6	12.8	1.88	4.8	8.3	16.6	..	19.0	19.5	10.6	72.5	83.0	60.6	3.4	13.5	39.4	23.9	14.8	14.8
92.8	92.1	4699	23.3	12.1	1.86	4.3	8.6	16.1	6.4	19.5	18.6	10.2	68.6	82.1	59.4	3.3	11.7	40.7	22.8	17.5	17.5
93.5	93.0	4890	24.2	12.2	1.67	4.4	8.6	16.8	..	20.0	19.2	10.4	69.4	82.3	60.2	3.1	11.2	39.8	24.2	15.6	15.6
16.0	15.9	20	15.9	9.0	0.3	3.0	4.2	7.6	3.3	13.0	11.9	8.7	68.6	82.1	59.4	2.7	9.6	30.8	15.7	14.1	14.1
93.5	93.0	4890	24.6	12.9	1.9	4.8	8.6	16.8	6.4	20.0	19.8	12.6	75.2	91.9	70.1	4.8	13.5	40.7	24.2	19.4	19.4

Although the tails of some other blennioids have been examined, no work, so far as we know, has been done on *M. americanus*. Therefore, six tails were cleared and stained after the method of Cumley, Crow and Griffen (1939). This caudal fin (Fig. 15 C) is obviously a highly specialized homocercal type, and its general features compare closely with that of another blennioid fish, *Cristiceps argentatus*, described by Whitehouse (1910). The urostyle is inconspicuous. Hypaxially the last vertebral segment possesses two hypural plates, of which the uppermost is the longer and generally less stout, extending posteriorly on a direct line with the vertebral axis. There is a prominent dorsal caudal radial, not to be confused with the uroneurals of Hollister (1936), since it is unpaired. The penultimate vertebra possesses a strong hypural, whose much smaller dorsal counterpart, unlike that in *C. argentatus*, cannot be considered an epural because it does not bear any fin rays at its distal end. The small ray-bearing cartilages described by Whitehouse as lying dorsal and ventral to the distal portions of the last two hypurals in *C. argentatus* are not apparent in *Macrozoarces americanus*.

SYNONYMS AND REFERENCES

- Blennius americanus* Bloch and Schneider, 1801: 171 (Latin descr.).
Blennius anguillaris Peck, 1804: 52, pl. 2, fig. 3 (descr., food); Jordan, 1919: 325 (orthotype for *Macrozoarces* Gill, 1864).
Blennius labrosus Mitchill, 1815: 375, pl. 1, fig. 7 (descr., color); Gill, 1898: Concordance (name).
Blennius ciliatus Mitchill, 1815: 374, pl. 1, fig. 6 (descr., color, N. Y.); Gill, 1898: Concordance (name).
Zoarces labrosus, Cuvier, 1829: 240 (comment on larger specimens in America); Cuvier and Valenciennes, 1836: 466, fig. 342 (Le Zoarcès a grosses lèvres, descr.); Richardson, 1836: 93 (name); Richardson, 1837: 207 (name); Cuvier, 1836-1849, 7: 175 (same as above).
Zoarcus labrosus, M'Murtrie, 1831: 177 (after Cuvier, in Eng.); Carpenter and Westwood, 1878: 294 (after Cuvier, 1829).
Blennius anguillarius, Williamson, 1832: 151 (Snakefish).
Blennius viviperus, Smith, J. V-C., 1833: 553, (name).
Blennius viviparus, Smith, J. V-C., 1835: 537 (name, Mass.).
Zoarces Gronovii Cuvier and Valenciennes, 1836: 469 (Le Zoarcès de Gronovius); Richardson, 1837: 207 (name); Storer, 1846: 375 (descr.).

Zoarces fimbriatus Cuvier and Valenciennes, 1836: 468 (Le Zoarcès frangé, descr., notes possibility of its being same as *labrosus*); Richardson, 1837: 207 (name); DeKay, 1842: 156, pl. XVI, fig. 44 (descr., color, finds scarcely any difference between this and *anguillaris* except in color; notes smaller size of *fimbriatus* compared with *anguillaris*.); Storer, 1846: 375 (descr.); Gill, 1864: 259 (mentioned in relation to *Z. anguillaris*).

Zoarceus labrosus, Cuvier, 1836-1849, 8: pl. 79, fig. 1 (Le Zoarcès au grandes lèvres).

Zoarchus labrosus, Storer, 1837: 348 (comment, Mass. Bay), 356 (name only).

Zoarcus anguillaris, Storer, 1839a: 66 (color, descr., food, palatability); Storer, 1839b: 374 (same as above).

Zoarces anguillaris, DeKay, 1842: 155, pl. XVI, fig. 45 (color, descr., appearance in commercial market, etc.); Storer, 1846: 375 (descr., loc.); Storer, 1855: 263, pl. XVII, fig. 4 (color, descr., food, seasons, Mass. and N. H.); Günther, 1861: 296 (color, range); Gill, 1862: 45 (common names); Holmes, 1862: 101 (seasonal abund., color, descr.); Gill, 1864: 259 (mentioned in relation to *fimbriatus*); Abbott, 1868: 818 (abund., associates, N. J.); Gill, 1873: 797 (range); Yarrow, 1877: 206 (original Fort Macon, N. C. record); Jordan and Gilbert, 1879: 371 (N. C., after Yarrow); Jones, 1879: 90 (common, Nova Scotia); Goode and Bean, 1880: 9 (coloration of young and black spot on dorsal); Günther, 1880: 498 (size, general discus.); Bean, 1881: 82 (duplicate specimens from Me. and Mass., distrib. by Smithsonian Inst.); Jordan and Gilbert, 1882: 784 (descr., color, range); Goode, 1879: 31; Goode, 1884: 236, pl. 67 (top fig.) (common names), 247 (common names, commercial position, general discus.); Bean, 1884: 340 (name); Gill, 1885: 179 (used for descr. of *Lycodoidea*); Kingsley, 1885: 259 (general comment); Whiteaves, 1886: 151 (Canad.); Jordan, 1887b: 912 (name); Jenkins, 1887: 92 (name, after Yarrow); Jordan, 1887a: 29 (name); Nelson, 1890: 755 (color, descr., abund., N. J.); Cox, 1895a: 40 (Canada); Cox, 1895b: 73 (New Brunswick, Canada); Jordan and Evermann, 1896: 478 (check-list, range); Bean, 1897: 371 (appear. in fall and winter); Jordan and Evermann, 1898, 3: 2457 (descr., synon.), 4: pl. 348, fig. 850; Gill, 1898: Concordance (name); Smith, H. M., 1898: 106 (abund. in fall, Vineyard Sound, Mass.); Southwick, *et al.*, 1900: 52 (name); Bean, 1903: 674 (descr., color, abund., food, range, N. Y.

and elsewhere); Schmitt, 1904: 286 (Anticosti I., Gulf of St. Lawrence); Jordan, 1905: 518, fig. 468 (general discus. of Zoarcidae); Fowler, 1906: 406, fig. (descr., N. J.); Halkett, 1906: 364 (Gulf of St. Lawrence); Tracy, 1906: 85 (R. I.); Halkett, 1907: 340 (Canada); Smith, H. M., 1907: 378, fig. 173 (characters, N. C.); Kendall, 1908: 135 (common names, New Eng.); Fowler, 1909: 407 (name); Kendall, 1909: 224 (Labrador), 228, 229, 236, 241 (Anticosti I.); Tracy, 1910: 152 (R. I.); Fowler, 1911: 15 (name); Cornish, 1912: 80 (P. E. I., Canada); Halkett, 1913: 113, pl. XII, figs. 146, 147 (Canada); Sumner, Osborn and Cole, 1913: 768 (loc., south. Cape Cod); Nichols, 1913: 104 (abund., season, N. Y.); Bigelow, 1914: 113 (loc., depth, abund., Gulf of Maine); Kendall, 1914: 63 (range, coll., Me.); Nichols, 1916: 10 (caught throughout year 1915, off N. Y.); Nichols, 1918: 116 (name, abund., N. Y.); Clemens, 1920: 3 (see Clemens and Clemens); Clemens and Clemens, 1921: 69-83, Fig. 1 and tables (histor., distrib., refs., migration, age and growth, reproduction, temp. relation to migration, food, associates, parasites); Willey and Huntsman, 1921: 6 (observ. on fish in aquarium, feeding habits, swimming movements, reactions to touch); Huntsman, 1922: 67 (abund., habits, loc., Bay of Fundy); Jordan, 1925: 728, fig. 636 (same as above); Bigelow and Welsh, 1925: 378, fig. 190 (descr., color, size, range, occur. in Gulf of Maine, habits, food, growth, breeding, commercial importance); Manter, 1926: 9 (trematodes); Nichols and Breder, 1926: 161, fig. (distrib., occur., observ. on use of dorsal spines, food, life history, size, N. Y., Me.); Borodin, 1928: 34 (young, Panama Atlantic; no doubt a misidentification); Jordan, 1929: 204 (common names, range); Breder, 1929: 277, fig. (occur., spawn.); MacKay, 1929a and b: 8, and figs. (digestive action) 24 (bile); Schroeder, 1931: 44 (name, loc.); Roule and Angel, 1933: 85 (name, loc.); Gregory, 1933: 374, 376, figs. 253, 254 B. (osteology, class.); Vladykov, 1934: 107 (footnote); Vladykov and McKenzie, 1935: 107, fig. CXX (abund., Nova Scotia); Vladykov and Tremblay, 1935: 81 (Canada); Bigelow and Schroeder, 1936: 337 (observ. on coll. of young, breeding, spawning, depth, growth, color, Gulf of Me.); White, 1939: 337, fig. 1 and 2 (observations on eggs, embryos and hatching, Bay of Fundy; not viviparous); Fischthal, 1944: 35 (observ. on parasite); Merriman and Warfel, 1944: 231-237 (relation to analysis of total fish populations and marketing); Sandholzer, Nostrand and Young, 1945: 1-12 (Ichthyosporidian-like parasite's abund., etc.).

Zoarchus anguillaris, Linsley, 1844: 64 (Block I., R. I. specimen, comments on larger size compared to specimens from within Long I. Sound); Storer, H. R., 1857: 263 (Bras d'Or, Labrador).

Zoarchus fimbriatus, Linsley, 1844: 64 (Long I. Sd., comments on smaller size of Sound specimens and probable identity with *anguillaris*).

Enchelyopus americanus, Gray, 1854: 101 (name).

Zoarcus viviparus, Bell, 1859: 208 (Marcouin, Gulf of St. Lawrence).

Zoarces ciliatus, Gill, 1862: 45 (common names); Abbott, 1868: 818 (abund., N. J.); Cox, 1895a: 40 (Canada); Cox, 1985b: 73 (New Brunswick, Canada).

Macrozoarces labrosus, Gill, 1864: 258 (suggested this name for American species).

Zoarces labrasus, Fortin, 1865: 65 (descr., Gulf of St. Lawrence).

Enchelyopus anguillaris, Gill, 1864: 258 (synon., proposed type of subgenus *Macrozoarces*); Fowler, 1916: 42 (N. J.); Fowler, 1917: 137 (Me. and Mass.); Fowler, 1920: 167 (N. J.); Fowler 1927: 116 (N. J.); Fowler, 1929: 613 (loc., time); Fowler, 1938: 308 (name only).

Eelpout, Nichols, 1918: 91 (descr., fig.).

Macrozoarces americanus, Jordan, Evermann and Clark, 1930: 473 (range, classif., synon.).

Ocean Pout, Merriman, 1944: 455, 456 (relation to marine resources; marketing and parasite).

Zoarces angularis, Fantham and Porter, 1943: 25, 27-29 (*Sarcocystis* in ocean pout).

? Postulated Blenny, Pennant, 1787: 115 (" . . . whole body spotted in form of small pustules; color pale dull yellow. Inhabits the sea off Newfoundland." No other characters are given, but color and postulated appearance suggest the possibility of its being *Macrozoarces americanus*.); Richardson, 1836: 93 (comments on inadequate description by Pennant, for which reason its position cannot be determined).

TABLE V. PERTINENT DATA ON THE COLLECTIONS OF OCEAN POUT (INVOLVING 2772 INDIVIDUALS) USED IN THIS STUDY. ALL CATCHES MADE BY MODIFIED OTTER TRAWL, UNLESS OTHERWISE STATED

<i>Date</i>	<i>Locality</i>	<i>No. of Fish</i>	<i>Depth (fathoms)</i>	<i>Bottom Temp. (°C.)</i>	<i>Remarks</i>
III-30-'43	Landed at Stonington, Conn.	5	.....	....	Sent by Conn. State Bd. of Fish & Game
IV-7-'43	2½-4 mi. off Watch Hill, R. I.	52	15-30	....	.....
IV-22-'43	2½-3 mi. off Watch Hill, R. I.	13	15-30	....	.....
V-11-'43	3-5 mi. W. of Montauk Pt., N. Y., 1 mi. off S. shore.	5	7-9	....	.....
V-11-'43	8 mi. SSE. of Montauk Pt., N. Y.	6	21	....	.....
V-11-'43	Landed at New Bedford, Mass.	49	.....	....	Caught in Nantucket Sd. (?)
V-25-'43	3-5 mi. W. of Montauk Pt., N. Y., 1 mi. off S. shore	6	7-9	....	.....
V-25-'43	3 mi. NNE. of Block I., R. I.	85	24-26	....	5 tagged
VI-15-'43	3 mi. NNE. of Block I., R. I.	67	24-26	....	.....
VI-15 to 16-'43	St. Andrews, N. B., Can.	4	.....	....	Line trawl
VI-15 to X-25-'43	St. Andrews, N. B., Can.	100	.....	....	Line trawl
VIII-7-'43	15 mi. SSE. of Pt. Judith, R. I.	6	20	....	.....
IX-9-'43	14 mi. SSE. of Pt. Judith, R. I.	4	22	....	.....
IX-12-'43	10 mi. S. by E. of Pt. Judith, R. I.	13	25	14.3	.....
XI-25-'43	12 mi. S. of Block I., R. I.	18	25	....	.....
XII-19-'43	5-8 mi. ESE. of Watch Hill, R. I.	2	10-14	6.3	.....
XII-30-'43	Old Harbor, Block I., R. I.	255	.....	....	.....
I-2-'44	Old Harbor, Block I., R. I., ¼ mi. from shore	837	23	4.7	.....
I-19-'44	Landed at New Bedford, Mass. Caught 6 mi. S. of Block I., R. I.	61	.....	....	.....
I-20-'44	Landed at Provincetown, Mass. Caught 10 mi. SW. of Wood End Light, Mass.	151	6	....	.....
II-20-'44	2 mi. S. of Green Hill, R. I.	2	12	1.5	.....
II-29-'44	8 mi. S. of Block I., R. I.	21	20-22	3.4	.....
III-12-'44	5 mi. SW. of Block I., R. I.	163	22	....	.....
III-10 to 13-'44	Landed at New Bedford, Mass. Caught at S. end of Nantucket Shoals	52	.....	....	.....
III-15-'44	Landed at Provincetown, Mass. Caught 8 mi. NNW. of Racepoint Light, Mass.	72	30	....	.....
III-19-'44	4 mi. N. of Block I., R. I.	4	20	2.4	.....

TABLE V. PERTINENT DATA ON THE COLLECTIONS OF OCEAN POUT (INVOLVING 2772 INDIVIDUALS) USED IN THIS STUDY. ALL CATCHES MADE BY MODIFIED OTTER TRAWL, UNLESS OTHERWISE STATED (cont.)

Date	Locality	No. of Fish	Depth (fathoms)	Bottom Temp. (°C.)	Remarks
IV-6-'44	3½ mi. N. of Pt. Herod, L. I., N. Y.	150	22	....	.....
IV-19-'44	3-4 mi. S. of Watch Hill, R. I.	95	17-25	3.8	45 tagged
IV-23-'44	3½ mi. S. of Watch Hill, R. I.	21	20	....	.....
V-18-'44	2 mi. SE. of New London, Conn.	5	10	8.7	4 tagged
V-30-'44	3-4 mi. ENE. of Block I., R. I.	123	25	....	.....
V-30-'44	Landed at New Bedford, Mass. Caught 8 mi. SW. of entrance to Muskeget Chan.	105	18-19	....	.....
V-30-'44	Landed at Provincetown, Mass. Caught 2 mi. E. of Peaked Hill Buoy, Mass.	102	25	....	.....
X-26-'44	5-6 mi. off Charleston, R. I.	1	.....	14.4	.....
XII-18-'44	2 mi. S. of Charleston Inlet, R. I.	61	14	6.5	.....
II-4-'45	5 mi. SSW. of Charleston, R. I.	24	.....	....	.....
III-5-'45	4 mi. S. of Green Hill, R. I.	9	20	1.8	.....
IV-16-'45	1-3 mi. NNE. of Block I., R. I.	23	20	4.6	.....

LIFE HISTORY

INTRODUCTION

Approximately 2800 ocean pout have been used as a basis for this study (Table V). The great majority of these specimens were collected from the catches of commercial fishermen from 1943 to 1945, and in most instances the gear used was a modified otter trawl. Wherever possible random samples were obtained by taking whole hauls from the day's catch, thus avoiding any bias which might arise from picking out the individuals to be studied; this also insured fair samples of the catch and, at least within the range of the selectivity of the gear, of the population. At the time of most of the collections an investigator from the laboratory was on board the vessel in order to assure accuracy and make pertinent field notes and observations; the samples were iced and barrelled on board and trucked to New Haven shortly after landing. Data were usually taken on the fresh fish in the laboratory within 24 hours; these included length, weight, otoliths, sex (gonads preserved), stomach contents (preserved), vertebral

counts, examination for parasites, etc. At times the samples were so large as to make it impossible to take full data, and in such instances various observations were omitted as dictated by necessity. On occasions, parts of the sample were frozen and withdrawn for study day by day, and sometimes extra data, such as that used for taxonomic purposes, were taken.

Lengths were recorded in half centimeters on a measuring board with an offset vertical head piece. It was standard practice to measure from the tip of the snout (which protrudes well in advance of the lower jaw) to the end of pointed caudal fin, there being no other convenient method. Slight inconsistencies in measuring undoubtedly occurred owing to the size of the fleshy upper lip and the degree to which the specimen was pushed against the head board; also on the few occasions when living fish were measured we found extreme difficulty in obtaining accurate length measurements (p. 40). But these errors were minimal, and variations of this sort are inconsequential as compared to the natural variability of fish populations as studied from large samples (Ricker and Merriman, 1945).

Further description of materials and methods are given under the appropriate sections in this paper. It should also be added that Table V does not include a number of specimens which were borrowed for study or specially preserved for us by different commercial fishermen; these were all small individuals which aided immeasurably in age and growth-rate determinations, but were not products of the more standard collections on which this work is chiefly based.

SPAWNING HABITS

Comparatively little information is available from previous workers as to the spawning habits of ocean pout. The period over which spawning takes place has been in doubt, and until recently it has been a matter of conjecture as to whether or not this species is ovoviviparous like its European counterpart (*Zoarces viviparus*). Goode (1884) believed that spawning occurred in mid-summer in Massachusetts Bay, but Clemens and Clemens (1921), Bigelow and Welsh (1925) and Nichols and Breder (1926), on the basis of more adequate information, inclined to a fall reproductive period. White's (1939) observations on the nesting and embryos of the ocean pout were the first to provide clear proof that the young are not born alive, but rather that the egg masses are deposited in cavities and guarded by one or both parents.

In fact, apart from the close relationship of the North American *Macrozoarces americanus* to the European *Z. viviparus*, there is nothing to indicate anything but normal teleostean oviparity in the former species.¹

As pointed out previously, the collections were from the catches of commercial vessels and were in large majority confined to the months from December to June. No spawning populations were available for observations regarding the time and duration of the spawning period, age at maturity, etc. In fact, in the period from July through November only five samples of ocean pout involving 42 individuals were collected in 1943 and 1944 in southern New England waters (Table V). It is therefore necessary to reconstruct the events in the life history of the ocean pout in the summer and fall on the basis of extremely limited data.

In an attempt to determine the number of eggs produced each year by ocean pout of different sizes, counts were made on a series of six ovaries taken from fish of 55–87.5 cm. in length from the May 30, 1944, collection from the southern Cape Cod area. This particular collection was used because the maturing eggs were well developed by that date and were therefore easier to count without danger of confusing them with the extremely small eggs which presumably would have matured for a succeeding spawning. Apart from size, it was also possible to distinguish these two categories of eggs in the formalin-preserved ovaries on the basis of color (the maturing eggs being yellow, the others more nearly white) and texture (the maturing eggs being hard, the others being soft and flabby). The volume of the whole ovary was first obtained by water displacement, and the ovary was

¹ However, almost every conceivable grade of maternal dependence occurs in teleosts—for example, *Z. viviparus* “secretes a very fatty and mucous uterine fluid” which is probably absorbed by the developing embryo as in the sting-ray, *Trygon* (Needham, 1942). It is possible, therefore, that fertilization is internal and the early stages of development are ovarian in *M. americanus* for the eggs have only been taken late in development; but here again there is no evidence that this is the case, either from direct observation or from any anatomical modifications for internal fertilization and incubation, unless the median unpaired ovary be considered such. Instead it would seem that a high degree of parental care has been developed in the closely-related European and North American species by different methods—the former accomplishing this end by ovoviviparity, the latter by one or both parents guarding the developing embryos closely, the eggs being deposited in crevices and cavities as indicated by White’s (*loc. cit.*) discovery of a mass of eggs and two adults in a rubber boot taken in a trawl.

then cut into several parts, each of whose volume was similarly determined. Counts were then made on one or several parts of each ovary and the number of eggs in the whole gonad calculated accordingly. To check the accuracy of this method, individual calculations of the total number of eggs in each ovary were made from actual counts on each of the parts into which three of the ovaries had been cut. This obviously enabled a comparison of the estimates of the total number from the counts on the different parts, as well as a comparison of the number calculated with the total number actually counted in these three specimens. It was apparent that calculations of total numbers based on parts of an ovary which constituted less than approximately one-third of the whole were subject to a possible error of as much as 15 per cent. But when counts were made on pieces that were between one-third and one-half of the whole gonad, the estimates of the total number of eggs were accurate to less than two per cent (*i. e.*, 2% variations between the different calculations as well as between the calculations and the actual total count). The number of maturing eggs showed a clear-cut tendency to increase with increase in size of the individual as shown by the actual lengths and counts listed below:

<i>Length of fish</i>	<i>Number of eggs</i>
55.0 cm.....	1306
59.0 cm.....	1362
67.5 cm.....	1902
68.0 cm.....	1673
72.5 cm.....	2260
87.5 cm.....	4161

Fig. 7 provides evidence that spawning occurs in southern New England waters in late September and October. The upper graph shows the seasonal trend of the percentage of the weight of the fish occupied by the ovary in mature individuals over a full year. Ovaries from representative samples of the ocean pout in most of the collections were dissected out, labelled individually, and preserved in the course of the routine analyses of fresh material. Subsequent inspection of this material indicated that in general all females above 57.5 cm. were mature in the sense that the larger eggs in the ovary would have been spawned in the next season. Therefore, the ovaries from individuals over this length in a series of collections over the year were weighed and the percentage of the weight of fish occupied by the gonad at

different dates was calculated. The figures obtained are inserted next to the appropriate points on the graph, and the broken line drawn through the points indicates the general trend. It is apparent from these data that spawning probably occurs between mid-September and late November, and since the gonads from fish in the November collection showed none of the characteristics of recently "spent" reproductive organs, it seems reasonable to infer that spawning had been completed some weeks previously—probably in October. However, the number of specimens at each point on the upper graph in Fig. 7 varies from as few as one in several samplings (unfortunately at the critical dates in August, September and November) to as many as 48. It is therefore evident that conclusions as to the exact time and duration of the spawning season based on these data are subject to possible error and should not be regarded as more than tentative. The chances are that the points in August and September are reasonably accurate indications of the general trend; this is especially true because the percentage variation in different individuals from large samples was not of sufficient magnitude to indicate that the points in the late summer would have been changed enough to alter the general slope of the curve materially had there been larger numbers involved. On the other hand, the point in late November may or may not be an accurate indication of the general ovarian condition of the population at that time. The single female on which this point is based might have been an exceptionally early spawner so that the general curve as drawn may place the spawning period somewhat too early. However, although there was only one female out of the collection of 18 individuals on this date which was over 57.5 cm. (the arbitrary limit of maturity as determined by inspection for this immediate purpose, p. 70), there were a number of females from 48–57 cm. in length. It is highly probable that some of these individuals were mature—*i. e.*, had spawned in the preceding month (see section on Age at Maturity). Since they showed essentially the same ovarian status as the single female on which the November point is based, it is reasonable to infer that this point is probably representative of the general condition of the population.

Several other matters in regard to the upper graph in Fig. 7 deserve consideration. First, on the basis of the available data there is good indication that the percentage of the weight of the females occupied by the ovary at any particular date tends to increase with increase in

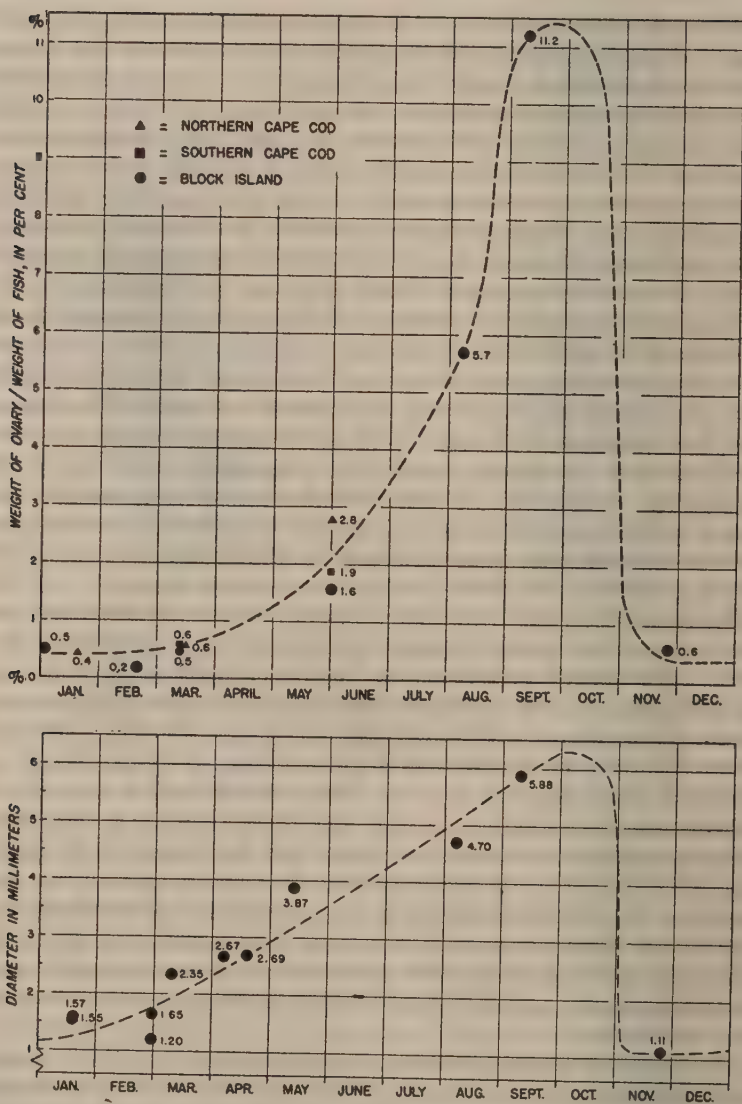


Figure 7. Seasonal trends in the percentage of the weight of mature ocean pout occupied by the ovaries (upper graph), and in egg diameters (lower graph). See text.

size of the fish. This trend, although small, was apparent in most of the samples on which the points in Fig. 7 are based where there were sufficient numbers of individuals. For example, the ovaries of fish from 57.5–62.0 cm. in length in one of the March collections occupied an average of 0.43 per cent of the weight of the fish, while those in the 62.5–67.0 cm. group in the same collection occupied an average of 0.54 per cent. Similarly, the ovaries in the 57.5–62.0 cm. group in another of the March collections averaged 0.42 per cent, while those in the 67.5–72.0 cm. interval averaged 0.79 per cent. The average percentages from the three May 30, 1944, collections, tabulated below with the numbers of individuals in each case enclosed in parentheses, provide further evidence of this trend:

Locality	Length intervals (cm.)		
	57.5–62.0	62.5–67.0	67.5–72.0
Northern Cape Cod.....	1.1% (5)	3.2% (6)	3.9% (5)
Southern Cape Cod.....	1.8% (15)	1.7% (15)	2.4% (5)
Block Island.....	1.6% (22)	1.5% (8)	.....

It thus appears that ovarian growth in mature individuals is not directly proportional to the growth of the fish. Put another way, it might be said that ovarian growth apparently fails to slow down at a rate commensurate with the successively smaller annual growth increments of the adults; instead, as might be expected from the fact that the ovaries develop and become functional later than other organs, growth continues in them at a rate which is faster than that of the rest of the fish.

The upper graph in Fig. 7 also provides some evidence that there may be slight differences in rates of maturation (and therefore possibly in times of spawning) in different geographical localities. Thus it will be seen that in the May 30, 1944, collections the values for the percentage of weight of the fish occupied by the ovaries decrease from north to south. While the differences are relatively small, it is significant that these figures are based on good-sized samples (17 from northern Cape Cod, 35 from southern Cape Cod, and 30 from the Block Island Sound area). If this conception is correct, and if the trend here indicated were maintained throughout the period of maturation, it would mean that spawning probably occurs earlier in northern waters and progressively later in southern waters. This in turn might be taken as evidence that spawning is, in part at least, either directly

or indirectly temperature-controlled—*i. e.*, reproduction takes place within certain temperature limits which are attained later in the year from north to south. In this connection, Clemens and Clemens (1921) believed that fertilization in the Bay of Fundy occurred in mid-September where the temperature of the water is roughly 9–11° C. This is somewhat earlier than our own evidence for the southern New England area as a whole and tends to substantiate further the conception of a correlation of spawning with temperature. It is significant in this connection that at the time of the collection of September 12, 1943 (when ocean pout approaching full maturity were taken), the bottom temperature was 14.3° C., while on December 19, 1943 (when spawning had been completed), the bottom temperature was 6.3° C. (Table V).

Added evidence that the spawning period in southern New England waters occurs in late September and October is provided by the seasonal trend in the diameters of maturing eggs (lower graph, Fig. 7). Eggs were dissected out of the mid-region of a series of ovaries from fish 57.5 cm. or more in length which had been taken in different months during 1943 and 1944. Each point on the graph is the average of measurements on 50 eggs from one ovary; these measurements were made on each egg separately with a pair of dividers to the nearest 1/64th of an inch, the longest axis being taken when the eggs were not perfectly spherical. The majority of this work was done without the aid of magnification and is therefore subject to a certain amount of error. However, the constancy of the individual measurements on the maturing eggs in different ovaries, and the small range in the diameters at any particular date as opposed to the seasonal differences in egg size, indicate that the errors from this method of measurement are insignificant in their effect on the general trend. Objection to this method can also be made on the basis that single ovaries were used in order to obtain each point at each particular date in most instances. The possibility of this method giving rise to serious error was precluded by the examination of all the ovaries in each of the collections before egg measurements were made, and the selection of a maturing organ which was typical of the sample. Also, in the collection of January 19, 1944, the eggs from the two ovaries were measured and the same average figure was obtained (Fig. 7). The fish whose ovaries were used for the egg-diameter studies were all taken south and west of Cape Cod. It is thus clear that this method of



Figure 8. Female ocean pout coiled around its infertile eggs. This photograph is reproduced here by kind permission of the Director of the John G. Shedd Aquarium, Chicago, Illinois.

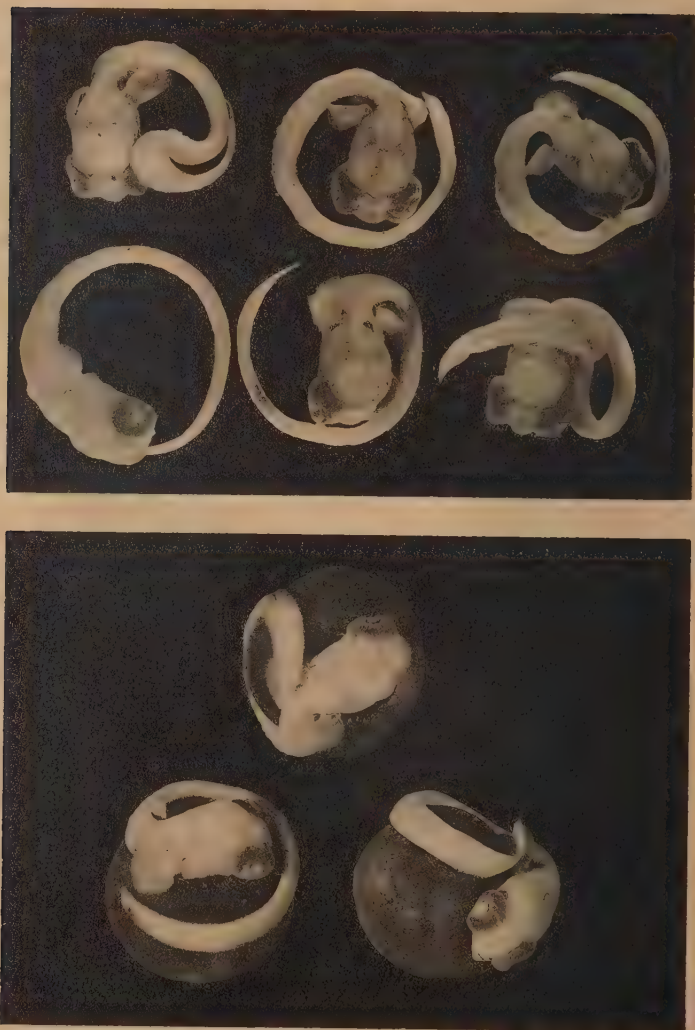


Figure 9. Developing embryos of the ocean pout. Material loaned by the Museum of Comparative Zoology, Harvard College, and originally recovered from the stomach of a cod taken on Cholera Bank, N. Y., November 16, 1927. Egg shells have been removed, and in the upper picture the embryos have been dissected away from the yolk sac.

determining the spawning period corroborates the information derived from plotting the seasonal trend of the percentage of the weight of mature individuals occupied by the ovaries, and that the two graphs in Fig. 7 in general agree closely.

Summing up the available evidence, it seems probable that spawning occurs in late September and October in southern New England waters. There is also good reason to believe that spawning takes place at progressively later dates from north to south over the range of this species, so that the period of reproduction along the Atlantic coast extends from mid-September in the north (Bay of Fundy) to at least late October in the south (New York and New Jersey waters). It is evident from the paper by White (1939) (see discussions on pp. 36 and 68) that the eggs are laid in crevices and protected by one or both parents. That the female gives the eggs close protection is further demonstrated in Fig. 8, which shows an individual coiled around a batch of infertile eggs it laid in captivity. Evidence is presented that spawning occurs on rocky bottom for the most part within the 30-fathom contour (p. 41), and it seems probable that reproductive activity takes place when the bottom temperature reaches approximately 10° C.

AGE AND RATE OF GROWTH

Developmental period and growth of the young. Evidence has been presented in the preceding section to show that ocean pout spawn in September and October. Little information is available on the length of time from fertilization to hatching other than that provided by White (1939) and by the embryos pictured in Fig. 9. White collected a mass of eggs in the Bay of Fundy in early January which hatched within several hours, thus indicating an advanced developmental stage. If Clemens and Clemens (1921) are correct in their assumption that spawning occurs in this region in September, the period of development in these waters must occupy roughly three and a half months. The young were approximately 30 mm. in length at the time of hatching.¹ The embryos shown in Fig. 9 were removed from the stomach of a cod taken on Cholera Bank off New York on November 16, 1927. That they were well advanced in development is obvious from the

¹ By contrast to the condition in salmon and trout, White noted that immediately upon hatching the yolk sac began to shrink, forcing the yolk into the abdomen. "The time from the moment of hatching to the complete external disappearance of the yolk did not exceed twenty seconds."

plate.¹ As a matter of fact, in order to be certain of the identity of these eggs, fin-ray counts were made on several individuals after removing the egg shell and dissecting the embryos away from the yolk. These counts (dorsal, 133-135; anal 110), the typical ocean-pout appearance of the head, lips, *etc.*, as well as the size of the egg (6-7 mm.) and the season at which they were taken, eliminated all other known species in the region. These embryos measured roughly 15.0-17.5 mm. in length (little more than half the length of White's newly hatched individuals), and they had not yet developed the typical apparent gap in the dorsal fin which White shows in his illustration. It seems clear that the eggs from Cholera Bank had some time to go before hatching—at least a month or more in all probability. If the view of later spawning in more southern waters (p. 73) be accepted, however, the developmental period from fertilization to hatching must be considerably shorter than in the Bay of Fundy region. The stage of the Cholera Bank embryos, as well as the fact that mature ocean pout have presumably completed the parental care of their eggs by late December (p. 42), indicate that the developmental period occupies approximately two and one-half months in southern New England, New York and New Jersey waters. This would mean that the period from fertilization to hatching extended roughly from early October to mid- or late December, approximately a month less than in the Bay of Fundy.

Only limited information is available in regard to the growth of the young after hatching. Bigelow and Schroeder (1936) stated:

Many small specimens from 1.8 inches long upward, have recently been collected along our coast between Maine and New Jersey, including (within the gulf) Mount Desert, Stellwagen Bank, Georges Bank, and the vicinity of Chatham, suggesting that the eelpout breeds successfully throughout this range. And as all the young thus far taken have been caught in depths of 20 to 45 fathoms, probably this is the usual spawning zone.

The sizes, in different months, of the young fry show that eelpouts in the Gulf of Maine grow to a length of about 2 inches in the first 6 months of their lives, and 3 inches in 9 months, agreeing in this respect with the growth-schedule of Bay of Fundy eelpouts derived by Clemens and Clemens (1921, p. 74) from the annual rings on the otoliths. Small specimens 5 to 6½ inches long taken from February to May are probably about 1½ years old.

Apart from the newly-hatched individuals described by White (1939),

¹ Note that the developing embryos are not consistently sinistral or dextral in their coiling—*i. e.*, they apparently coil indiscriminately to left or right.

the smallest ocean pout reported in the literature are those of Clemens and Clemens (1921), who recovered one 37 mm. in length from the stomach of a sculpin (*Myoxocephalus octodecimspinosus*) seined in St. Andrews Bay on April 15, 1919, and another imperfect specimen 25 mm. long from the contents of a shrimp trawl which was operated in the Bay of Fundy on April 21, 1919. There seems to be "... no doubt but that these small specimens were produced during late fall or early winter."

The following records of capture were provided through the kind interest of W. C. Schroeder, and represent a partial summarization of the data available to him from the collections at the Museum of Comparative Zoology and his own field notes.

Month	Locality	Depth (fathoms)	Temp. (°C.)	Length (mm.)
Feb.	73° 14', 40° 04'.....	28	...	154, 167
Apr.	73° 21', 40° 05'.....	...	...	41, 58
	71° 45', 40° 41'.....	31	...	48, 51, 54, 55, 60
	3 mi. S. Great Duck Is., Me. . .	28-33	2.7	41, 45
	2½ mi. ESE. Little Duck Is., Me.	20	2.7	48, 52, 127
May	73° 27', 39° 05'.....	35	...	70
	70° 47', 41° 05'.....	23½	...	64
	69° 41', 41° 38'.....	28	...	45, 46, 50, 52, 53
June	69° 41', 41° 39'.....	29	...	63, 75, 125, 150, 174
	Off Long Is., N. Y.....	...	...	54, 62, 63, 66
July	70° 19' 30'', 42° 17'.....	17-25	...	70, 73, 73
Aug.	66° 18', 41° 51'.....	45	...	101

Assuming that the smallest individuals in these records were products of the previous fall's spawning—an inescapable conclusion in view of the information at hand (*e. g.*, White's observation that the embryos were roughly 30 mm. long at hatching), it is possible to estimate the rate of growth of the juveniles from the length data shown above. In April the range is from 41-60 mm., the average being approximately 50 mm. In May the range is from 45-70 mm., with the average falling close to 55 mm. In June the range is from 54-75 mm., the average length being nearly 65 mm. In July the 0+ fish are roughly 70 mm. or more in length. The two individuals taken in February in the above records were almost certainly 1+ fish, and this would mean that in general a 14-month ocean pout was 150-170 mm. long. There can be no doubt that the growth rates of ocean pout in different areas

differ materially (Fig. 13), so that the above estimates, based on limited data, are no better than broad generalizations.

Our own collections of small ocean pout have been limited, but they substantiate the conclusions reached from other sources of information. In the period from May 20-27, 1944, we obtained five small ocean pout from $71^{\circ} 37'$, $40^{\circ} 50'$ in 28 fathoms; these individuals were 72, 73, 77, 81, and 180 mm. in length; obviously the collection was composed of four 0+ and a single 1+ fish. The average length of the 0+ fish from this collection is somewhat above that derived from Schroeder's records, but is sufficiently close to indicate that the difference is no more than that which would be expected from seasonal, geographical, or other variations. Another collection of 14 small ocean pout from 170-295 mm. in length was made in June and July off Provincetown, Massachusetts. Of these, five were 1+ fish from 170-193 mm. in length and the remainder were apparently 2+ individuals as indicated both by the size grouping and otolith studies (p. 85). No other 0+ or 1+ ocean pout were obtained in our collections.

On the basis of these data it appears that ocean pout, with the possible exception of northern fish which apparently grow more slowly, are roughly 5-8 cm. (2-3 in. or more) approximately six months after hatching, 11.5-15 cm. ($4\frac{1}{2}$ -6 in.) in length when they are one year old, and about 18 cm. ($\pm$ at least 2 cm.) ($6\frac{1}{2}$ -8 in.) long 18 months after hatching. For the estimated average lengths at subsequent ages see Table VI. Fig. 10 is a drawing of a 73 mm. ocean pout in which careful attention has been paid to body proportions and general pattern. Note that there are regularly-spaced dark patches along the sides of the body, and that these decrease in intensity and pigmentation posteriorly. The black spot on the anterior part of the dorsal (p. 55) is also apparent, and observation of other specimens show that this ocellus is also prominent in 1+ fish but tends to fade out in 2+ fish; in other words, it is less and less conspicuous in individuals over 20 cm. and to all intents and purposes disappears in fish over 30 cm.

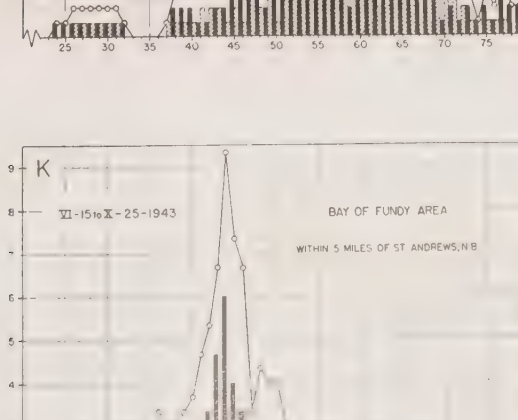
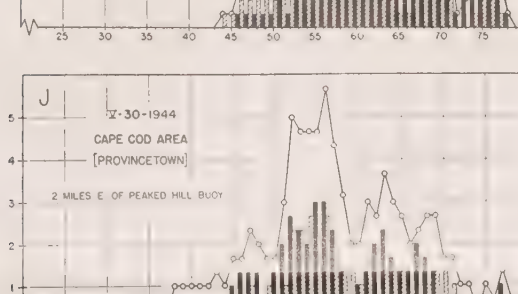
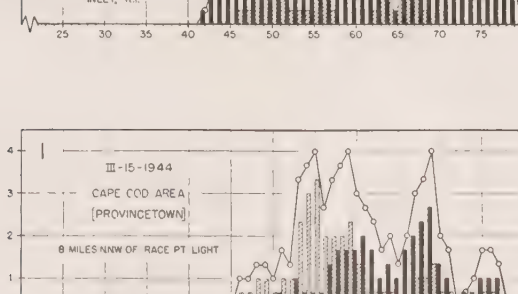
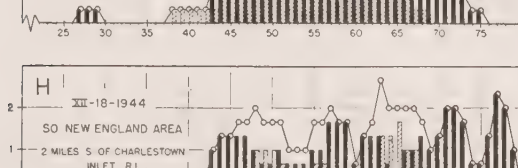
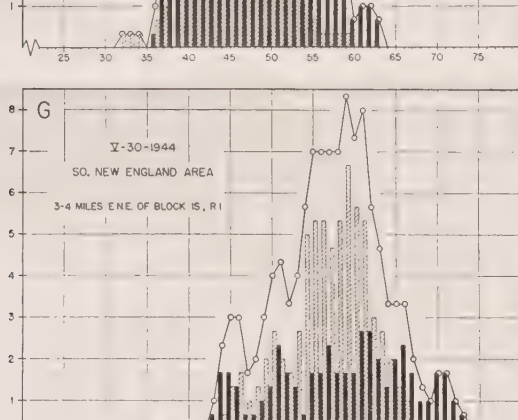
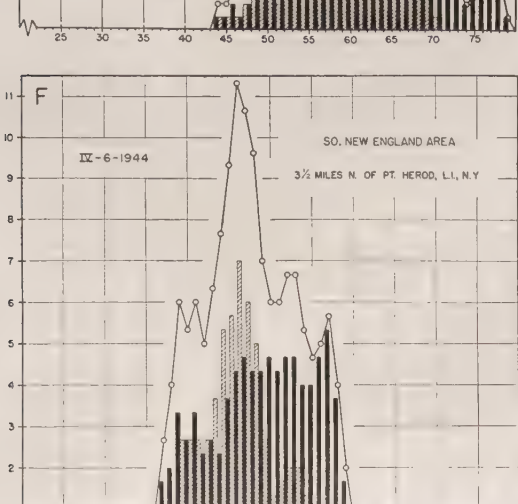
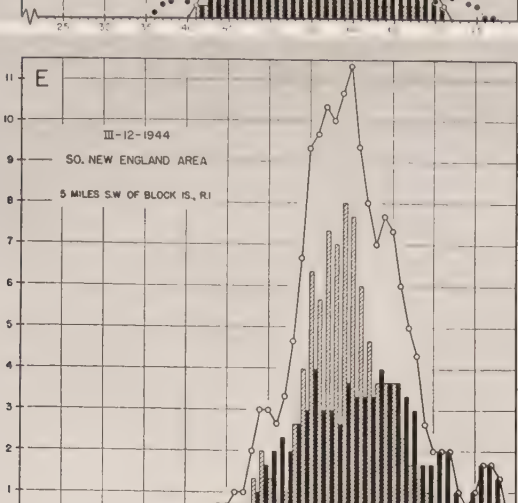
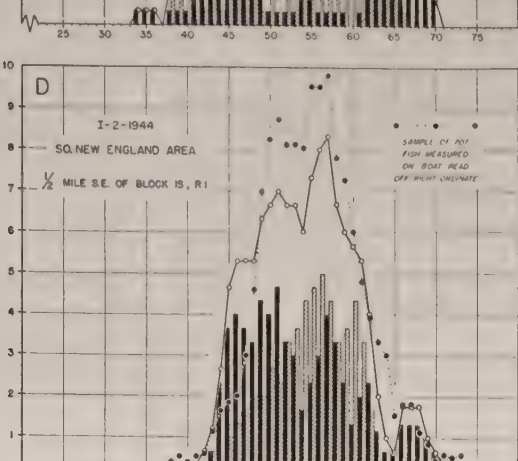
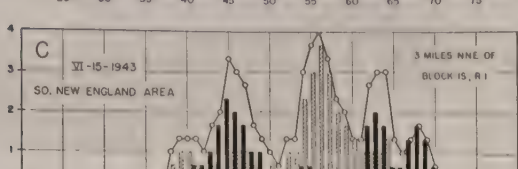
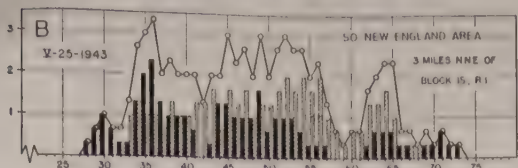
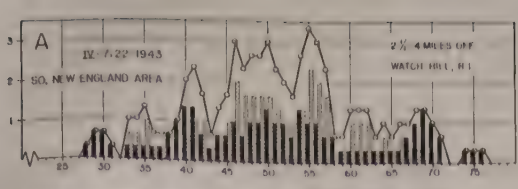
Length-frequency studies. In regard to the growth rate of older ocean pout which are taken in the commercial fishery, an attempt was made to derive information from the distribution and progression of the modes of length-frequency curves from a series of 11 random samples at different dates in various localities. These samples are graphed in Fig. 11. As indicated earlier (p. 67), in order to insure



Figure 10. Drawing of an ocean pout 73 mm. in total length after preservation in formalin. Specimen taken between May 20 and 27, 1944, near "G" buoy, 71° 37' W. and 40° 50' N.

random samples, all the ocean pout in at least one complete trawl haul were measured with two exceptions. On one occasion (Fig. 11D) the catch was so large that it was impossible to measure more than a small fraction of any single haul. Therefore, when the contents of the net were dumped onto the deck only the fish in a single checker (rectangular areas marked off by vertical partitions) were set aside and barrelled for subsequent analysis in the laboratory. This method of selection provided against any bias that might arise from an attempt to pick the sample by hand.¹ After this sample of 127 ocean pout had been set aside, those which spilled over into certain checkers in subsequent hauls throughout the day were measured on the boat. In Fig. 11D the solid line connecting the circles represents the random sample which was taken from the first haul; the dotted line connecting the black circles represents the 707 fish which were measured from subsequent hauls during the rest of the day. It is apparent from a comparison of the two length frequencies that there is close agreement between them. The faithful repetition of the irregularities in the smaller sample by those in the large sample provides good evidence for the adequacy of both the method used and number of individuals in the lot which was picked for laboratory analysis. There is, of course, a somewhat greater spread in the larger sample, but this is to be expected and in no way invalidates the conclusion as to the adequacy of the random sample taken from the first haul. The other occasion on which a length-frequency curve was not based on measurements of all the fish in one or more trawl hauls is shown in Fig. 11K. This lot of fish from the Bay of Fundy area was collected during the summer by set trawls (hook and line), and it therefore represents a different and incommensurable method of sampling the ocean pout population. In some ways the hook-and-line method offers advantages as a method of sampling the actual population in that it probably takes a better proportion of smaller individuals which are usually lost through the meshes of a trawl net. On the other hand, the hook-and-line method offers all sorts of chances for inaccurate sampling due to hook size, differential food preference of small and large individuals, *etc.* These inaccuracies are far less serious in the trawl net

¹ In selecting the sample by hand there is usually a tendency to favor the larger fish, since they are easier to pick up, and it is also difficult to avoid picking fish off the top of a pile with the result that the smaller individuals, which usually end up near the bottom of the pile, are inadequately represented in the sample.



ORDINATES = NO. OF FISH LENGTHS IN CM. MEASURED

LENGTH-FREQUENCY CURVES FROM 11 FISHING SURVEYS IN THE SOUTHEASTERN BAY OF FUNDY AREA, 1943-1944

DATA SMOOTHED BY TAKING 10% MEAN

	NO.	NO.	TOTALS
A	3	12	15
B	12	42	54
C	10	58	68
D	44	58	102
E	74	85	159
F	74	85	159
G	45	72	117
H	44	4	48
I	36	36	72
J	12	42	54
K	13	36	49

1. FISH AT 60 CM'S OMITTED IN I; 1. FISH AT 80, 84, 86, 93-94 CM'S OMITTED IN J; 1. FISH AT 16 CM'S OMITTED IN K

method with demersal species above the size which can escape through the mesh.

Let it be clearly understood that the random samples of the catch of the commercial trawlers which form the basis of all the length-frequency curves in Fig. 11, except K, are *not* random samples of the population. In a completely random sample of the population, including all the age classes, the whole curve would be skewed heavily to the right; that is, the slope near the left ordinate would be abrupt and steep to the peak, and the slope to the right of the peak would tend to be gradual and probably undulating. The more symmetrical or "normal" the length-frequency curves, the less random they are in terms of the total population. It is evident from the curves in Fig. 11 that nothing approaching a random sample of the population was taken in the commercial gear. The reason for this lies in the size of the mesh, which, below the maximum size of escapement, allows for an increasingly greater loss of the successively smaller individuals and therefore the more recent year-classes. The stretched mesh-size in the cod-ends of the trawl nets on the boats which made most of the collections used in this work varied from $3\frac{1}{2}$ - $4\frac{1}{2}$ inches. A 40-cm. ocean pout can escape through a 4-inch mesh without great difficulty, and it seems probable that some 50- to 60-cm. individuals would normally escape from a cod-end with a $4\frac{1}{2}$ -inch mesh. Under these circumstances the sampling of the population below 55 or 60 cm. is increasingly inaccurate for the successively younger age groups. From the information already presented on the growth of young ocean pout (p. 80), as well as from the corroborative data from otolith studies (p. 85), it is clear that a large number of 3+ fish normally escape from the commercial gear. Indeed it seems probable that 4+, 5+, and even some 6+ and 7+ individuals might escape under some conditions (see Table VI for average lengths at different age categories). In the light of these considerations it would appear that sampling of the ocean pout population by commercial trawlers only approaches reasonable accuracy after the sixth or seventh year of life.

In view of these limitations it is to be expected that the length-frequency method of age and growth determination from samples of ocean pout from the commercial trawler catches will not be highly productive. This is especially true since the length-frequency method is usually most applicable for age and growth studies of the *younger* year-classes. There is an increasing tendency after the first several

years for the modes to overlap to such an extent that they are not distinguishable unless year-class dominance or some other phenomenon makes the identity of a particular group possible. Examination of the curves in Fig. 11 shows that they provide only the most meager information as to age and rate of growth of the ocean pout. Taken as a group, they give clear indication of comparatively slow growth rate and the overlap of the modes of successive year-classes—indications which are borne out by otolith studies (p. 90). Neither do they give any consistent evidence of the phenomenon of year-class dominance having occurred in any of the age categories available to the commercial fishery in 1943 and 1944; this is not surprising, since the exceptional success of occasional broods is far more characteristic of species with large numbers of eggs and no parental care than it is of forms that produce limited numbers of eggs which are carefully guarded. The only possible indication of a dominant year-class is the recurring peak between 55 and 60 cm. in A, C, D, E and G; more probably, however, these peaks are emphasized by the above-mentioned errors in sampling the population, and contribution to them is almost certainly from at least several age groups as indicated by their failure to progress in orderly fashion over the period from April 1943 to May 1944. The graphs in Fig. 11 do show the general size range of ocean pout in the commercial catch, and it is clear from them that the vast majority of fish fall between 40 and 80 cm., with the peaks of abundance occurring between 45 and 65 cm.

Note also that the length-frequency curves have been broken down into their male and female components as indicated by the black and the diagonally lined bars respectively, with the totals of both sexes being shown by the solid lines connecting the circles. The general utility of this procedure is illustrated by Fig. 11C, where, in the absence of other data, the length-frequency curve for the whole sample might be considered as highly suggestive of separate modes which indicate different age groups. However, it is apparent from the composition of these modes that at least one is made up of a predominance of males, while another is made up of an overwhelming majority of females. Since the sex ratios from one year-class to another could hardly be expected to change from one extreme to the other, it seems more reasonable to suppose that the successive modes are the result of pure chance in this somewhat inadequate collection which consisted of only 64 fish. In the larger samples there are no comparable or con-

sistent modes. The recurring peaks between 55 and 60 cm. in A, C, D, E and G, which are almost universally composed of a heavy dominance of females, are peculiar. Here again a possible explanation may be found in the selectivity of the trawl net. As is shown later (p. 94), the length at maturity of the females is mainly between 45 and 60 cm. It is conceivable that the large ovary in the spring months makes the females just enough bigger around to prevent their escape through the meshes of the net, while males of similar lengths are thin enough to get out in relatively larger numbers. This would mean that the gear was actually selective for sexes at the length interval between 45 and 55 cm., and perhaps slightly above this level. The validity of this hypothesis is indicated by the situation in Fig. 11D, where the sex ratios of the fish comprising the 55-60-cm. peak are more normal. It so happens that the cod-end mesh used on this occasion was comparatively small ($3\frac{1}{2}$ in.), as compared to the $4-4\frac{1}{2}$ inch mesh used on the other collection dates. Furthermore, this collection was made on January 2, 1944—at a time when the ovary had not yet increased to such a great size preparatory to spawning; the other collections (A, C, E and G) were made later in the spring when the ovaries are much larger (Fig 7).

Otolith studies. Since age determinations of individuals above the 2+ category were not possible by length studies, and since scales of the ocean pout are so small and deeply imbedded as to make their use impractical (quite apart from the fact that on superficial examination they do not appear to be legible), otoliths were taken from the majority of fish in the different collections. Furthermore, the otolith method had already been used to good advantage by Clemens (1920) and Clemens and Clemens (1921) on this species in the Bay of Fundy. Otoliths were removed from the fresh specimens and placed in envelopes as part of the regular laboratory analysis; although these ear "bones" are small as compared to those of many species, they were not difficult to remove with practice.

The particular otolith studied was the sacculith (Adams, 1940) or sagitta; the utriculith (lapillus) and lagenalith (asteriscus) were much smaller and apparently illegible. The gross anatomy of the internal ear was found to be generally similar to that of *Zoarces viviparus* as described by Retzius (1881), whose illustration shows the general contour of the sacculith to approximate that of the American ocean

pout. On the other hand, the sacculith is quite different from that described and pictured by Frost (1929) for *Z. viviparus*, who stated "... the sagitta is narrow and flat." It may be that Frost's specimen was abnormal (and indeed the otoliths of the American ocean pout show great variation and many irregularities), or it may be that the mode of preservation caused some alteration in its morphology. In all events, the otolith of *Macrozoarces americanus*, as shown in Fig. 15B, is more or less circular in outline, with a characteristic notch and a somewhat variably pointed projection on its anterior margin. The extent of the notch and the size of the projection tend to increase with size, but here again there may be considerable differences between individuals of approximately the same length. The less obvious notch and projection in the otolith of a small individual (18.5 cm.) is shown in Fig. 15A. The medial surface of the otolith is flat or even slightly concave, with a shallow antero-posterior sulcus running through its center, while the lateral surface is distinctly convex with definite concentric layers, which, under magnification, give a descending staircase effect from the original center to the periphery of the otolith.

In general the surrounding membranous material was picked off at the time the otoliths were removed. Later the otoliths were examined under low magnification by transmitted or direct illumination, but most frequently by a combination of both. After a certain amount of experimentation it became standard practice to examine and measure each otolith dry as it rested in a watch glass on its medial surface. There seemed to be no apparent advantage from having the otoliths immersed in fluid, a variety having been tried; the sacculiths were more legible when viewed from the lateral surface. Measurements were made through the longest axis (from the projecting tip to the most posterior margin) by means of a micrometer ocular.

Before considering the age determinations resulting from the otolith studies, a few remarks on the relation of growth of the otolith to growth of the fish are in order. Attempts to obtain consistent and accurate measurements on otoliths are rendered difficult by the irregularities and variations in shape, even from fish of the same general size. The upper graph in Fig. 12 shows the length of the otolith plotted against the length of the fish in a typical sample of approximately 100 specimens; this provides a good indication of the range in size of the otoliths from fish of any particular length. Citing an extreme,

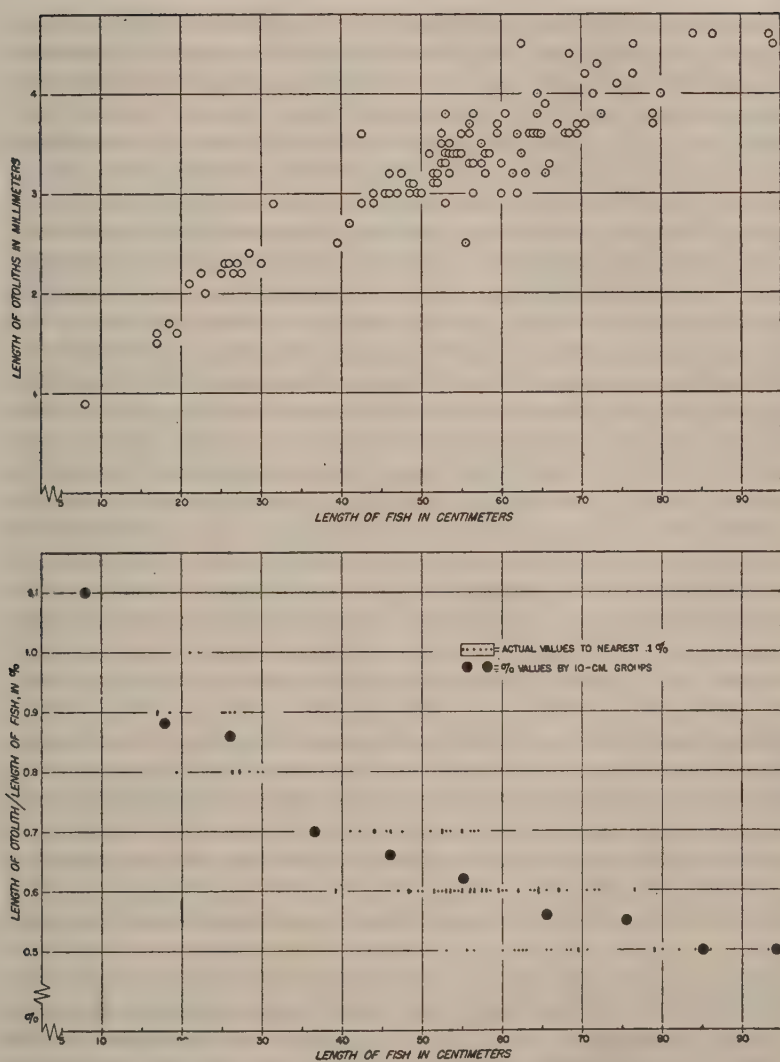


Figure 12. The relationship of the length of the otolith to the length of the fish. See text.

the range of otolith size in 62–62.5-cm. ocean pout is from 3–4.5 mm. Despite the spread at the different lengths, however, it is possible to establish the general trend of the relation of the growth of the otolith to that of the fish. This is more clearly indicated in the lower graph in Fig. 12, where the same data are plotted on the basis of the percentage of the length of the fish occupied by the otolith. It is obvious from these data that the fish grows proportionately faster than the otolith, and that the relationship appears to be exponential. Here again, the variability of the otolith is evident; for example, despite the fact that the growth of the otolith is apparently not proportional to the growth of the fish, individuals whose otoliths are 0.6 per cent of the length of the fish range all the way from 39–76.5 cm. It is perhaps true that the method of measurement, which included the anterior projection, introduced an error, since the projection may not grow at the same rate as the body of the otolith. But it seems unlikely that this would alter the general conclusion that the growth of the otolith is not directly proportional to the growth of the fish. Furthermore, reference to the middle graph in Fig. 6 indicates that the head grows faster than the body of the fish; that is, it occupies a considerably lower percentage of the standard length in smaller individuals than it does in larger fish. This would indicate that the relationship between the growth of the otolith and the growth of the head is even more disproportionate than that between otolith-growth and the growth of the whole fish. Of course it would be possible on the basis of more data to calculate a regression coefficient for the relationship between the growths of the otolith and the fish. However, for a solution of the ocean pout's life history this would appear to have limited utility, particularly because of the difficulty of obtaining accurate measurements from one ring to another on the otoliths when compared with the relative simplicity of measuring from one annulus to another on scales which grow proportionately to the growth of the fish.

As is evident from Fig. 15A and B, the otoliths show reasonably clear alternate dark and light bands which are capable of interpretation and enumeration after certain facts have been established. The method of computation used here has been much the same as that of Clemens and Clemens (1921), who noted the similarity of their own interpretation to that of Fryd (1901) for *Zoarces viviparus*. Clemens and Clemens were particularly careful to qualify their results, quoting

the work of Lea (1919), who in reference to the analysis of herring scales stated, "As a matter of fact, we are hardly justified in using the term 'age-determination' . . . ; 'estimate' would be more correct, for there will always be found, whatever may be the material under consideration, a greater or less number of individuals . . . where the decision must be based more or less upon personal judgment." We agree with this qualification; nevertheless the results of our work seem to substantiate the findings of Clemens and Clemens (Table VII). The regularity of the results and the agreement obtained from other lines of evidence indicate the reasonable accuracy of this means. There are many confusing matters, including the variation in the distinctness of the bands, the presence of secondary lines or false bands, and the crowding at the margins (Clemens and Clemens); but the greatest obstacle lies in the interpretation of the center of the otoliths of fish above 40 cm. in length. Without smaller individuals in which the kernel and surrounding areas are sufficiently clear to be diagnosed, it would be extremely difficult to know how to evaluate the center of the otolith. In only a few of the otoliths from fish over 40 cm. was the center legible, since this region becomes increasingly thick in older individuals and is therefore likely to be more and more indistinct no matter what type of illumination is used. In actual practice in our work the average diameters of the kernel and surrounding areas were established by the examination of otoliths from small fish. These values were then checked against the measurements of the similar region on otoliths from older individuals which could be interpreted. Since they agreed within reasonable limits throughout, it was possible to use these figures as a point of departure in less legible otoliths from larger fish. Referring to Fig. 15A, the central kernel appears to represent the winter in which the fish was born, the surrounding light area the spring and summer (?), the dark band the fall and winter, and the peripheral light region the spring. The fish from which this otolith was taken was caught in June and was approximately a year and one-half old at that time. It is interesting that the light "summer" band is so well formed by June, and it seems reasonable to think it may start to be laid down at least as early as April. In general in otoliths in which the central portion was legible, the winter kernel ranged between 0.67 and 0.95 mm. through its long axis, and the long diameter to the outer margin of the second winter band was 1.14-1.86 mm. Using these approximate values as indicators, it was usually possible

to establish the position of either the second winter or summer with a fair degree of certainty, and then to count the alternate light and dark bands with reasonable accuracy. In older fish the interpretation of the peripheral bands was sometimes confusing, so that it was difficult to be certain of the precise age, but even in fish over ten years old it was often possible to derive clear indications of the exact number of bands. The interpretation of the otoliths of the smaller fish agrees well with the information on age and rate of growth derived from the lengths of these individuals (p. 80), and there is every reason to suppose that the general method here used is valid within the limits of its accuracy.

Table VI shows the size-ranges at different ages, as well as the estimated average lengths of 1- to 17-year-olds. It is immediately obvious that this is a slow-growing species, and that the size-ranges of the different age categories overlap above the 4+ group, thus providing further evidence that the length-frequency curve method is not likely to be applicable (p. 83). On the average ocean pout in southern New England waters attain a length of 6 inches shortly after they become

TABLE VI. SIZE-RANGES OF OCEAN POUT AT DIFFERENT AGE CATEGORIES (0+ TO 16+), AND ESTIMATED AVERAGE LENGTHS OF 1- TO 17-YEAR-OLD INDIVIDUALS. DATA BASED ON OTOLITH ANALYSIS OF APPROXIMATELY 350 SPECIMENS FROM MASSACHUSETTS AND CONNECTICUT TAKEN DURING LATE MAY AND JUNE, 1944. SEE TEXT

Age Group	Estimated Average Lengths at different ages					
	Age	Cm.	Inches	Age	Cm.	Inches
0+....	½ yr. old..	7-8	2.8-3.1	1 yr. old...	13....	5.1
1+....	1½ yrs. old..	17-19	6.7-7.5	2 yrs. old...	22....	8.7
2+....	2½ yrs. old..	21-29	8.3-11.4	3 yrs. old...	31....	12.2
3+....	3½ yrs. old..	30-39	11.8-15.4	4 yrs. old...	40....	15.7
4+....	4½ yrs. old..	39-51	15.4-20.1	5 yrs. old...	48....	18.9
5+....	5½ yrs. old..	45-61	17.7-24.0	6 yrs. old...	56....	22.0
6+....	6½ yrs. old..	50-68	19.7-26.8	7 yrs. old...	63....	24.8
7+....	7½ yrs. old..	53-71	20.9-28.0	8 yrs. old...	70....	27.6
8+....	8½ yrs. old..	53-80	20.9-31.5	9 yrs. old...	76....	29.9
9+....	9½ yrs. old..	58-84	22.8-33.1	10 yrs. old...	81....	31.9
10+....	10½ yrs. old..	62-68	24.4-26.8	11 yrs. old...	85....	33.5
11+....	11½ yrs. old..	87	34.3	12 yrs. old...	89....	35.0
12+....	12½ yrs. old..	94	37.0	13 yrs. old...	92....	36.2
13+....	13½ yrs. old..	84	33.1	14 yrs. old...	95....	37.4
14+....	14½ yrs. old..			15 yrs. old...	97....	38.2
15+....	15½ yrs. old..			16 yrs. old...	99....	39.0
16+....	16½ yrs. old..	93	36.6	17 yrs. old...	100....	39.4

TABLE VII. RANGE IN SIZE OF OCEAN POUT OF DIFFERENT AGES IN THE BAY OF FUNDY AREA AS BASED ON OTOLITH READINGS ON 91 SPECIMENS BY CLEMENS AND CLEMENS (1921) AND 99 SPECIMENS TAKEN FROM JUNE-OCTOBER, 1943, BY OLSEN AND MERRIMAN

Age Group	Age	Clemens and Clemens		Olsen and Merriman	
		Number of Specimens	Length (cm.)	Number of Specimens	Length (cm.)
0+....	1st year.....	7.....	3.7-10.0.....	.....	.....
1+....	2nd year.....	3.....	12.0-14.7.....	.....	.....
2+....	3rd year.....	7.....	17.5-21.0.....	1.....	16.5
3+....	4th year.....	5.....	21.8-26.2.....	.....	.....
4+....	5th year.....	4.....	25.5-30.9.....	2.....	23.0-28.0
5+....	6th year.....	7.....	31.3-34.7.....	17.....	35.0-43.0
6+....	7th year.....	2.....	34.3-35.2.....	26.....	33.5-47.0
7+....	8th year.....	6.....	37.5-47.0.....	25.....	40.5-53.5
8+....	9th year.....	10.....	41.0-50.0.....	9.....	41.0-56.0
9+....	10th year.....	21.....	43.4-53.7.....	5.....	50.0-54.0
10+....	11th year.....	5.....	45.5-56.0.....	2.....	50.5-51.0
11+....	12th year.....	2.....	56.5-57.0.....	4.....	51.5-64.0
12+....	13th year.....	1.....	59.8.....	1.....	64.5
13+....	14th year.....	1.....	59.0.....	1.....	56.5
14+....	15th year.....	2.....	59.0.....	3.....	62.0-69.0
15+....	16th year.....	4.....	60.0-73.0.....	2.....	65.0-70.5
16+....	17th year.....	3.....	61.5-68.0.....	1.....	59.0
17+....	18th year.....	.....	.....	.....	.....
18+....	19th year.....	1.....	67.5.....	.....	.....

one year old, 12 inches when they are three years old, 24 inches a little before they become seven years old, and 36 inches when they are approximately 13 years old. Although detailed comparisons have not been made, there appear to be no striking differences between the growth rates of ocean pout from different localities in the general southern New England area. There is some indication that those from Connecticut and New York waters grow slightly faster than those from Massachusetts, but with the overlap in size-ranges at different age categories which occurs in any locality it would take large quantities of data to demonstrate constant and significantly different growth rates from the different localities in this area. There is also some slight indication that the females tend to grow a little slower than the males, since, in examining typical samples, the females of any age category show a tendency to predominate in the lower part of the size-range; but to establish this fact would require far more data than it has been possible to analyze in this study.

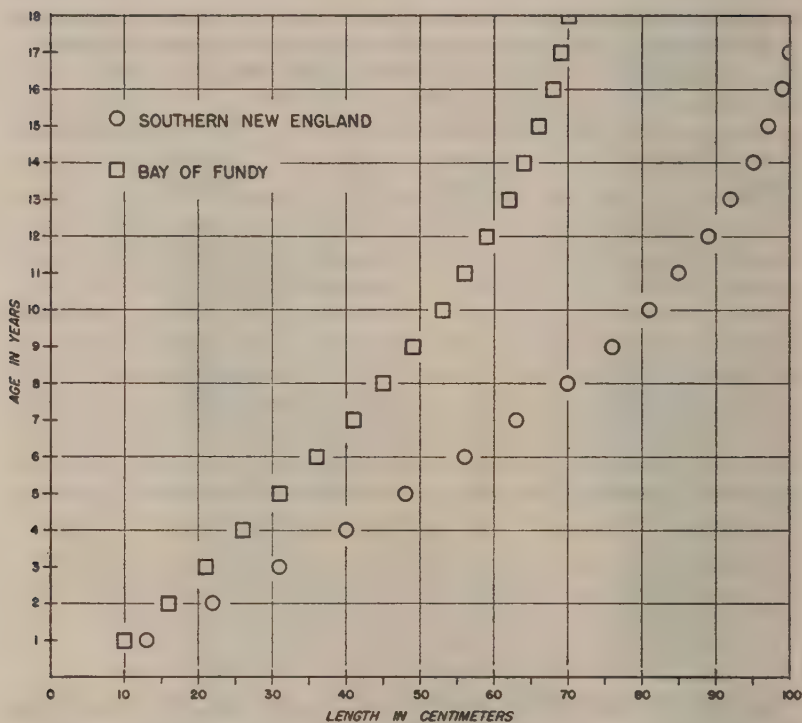


Figure 13. Average growth rates of ocean pout from the Bay of Fundy and from southern New England. Data based on estimated average lengths on 1- to 18-year-olds. See Tables VI and VII.

Comparison of the general growth rates of ocean pout in southern New England (Table VI) with those established by Clemens and Clemens (1921) for the Bay of Fundy revealed that the Canadian fish grow at a considerably slower rate. In order to make certain that our method of estimating age agreed with that of Clemens and Clemens we determined the size-range at different age categories from the otoliths of the collection of June–October, 1943, from St. Andrews, New Brunswick. This analysis was performed without reference to Clemens and Clemens table, and the results are listed on the right hand side of Table VII. Comparing these data with those of Clemens and Clemens, it is evident that there is close agreement between the

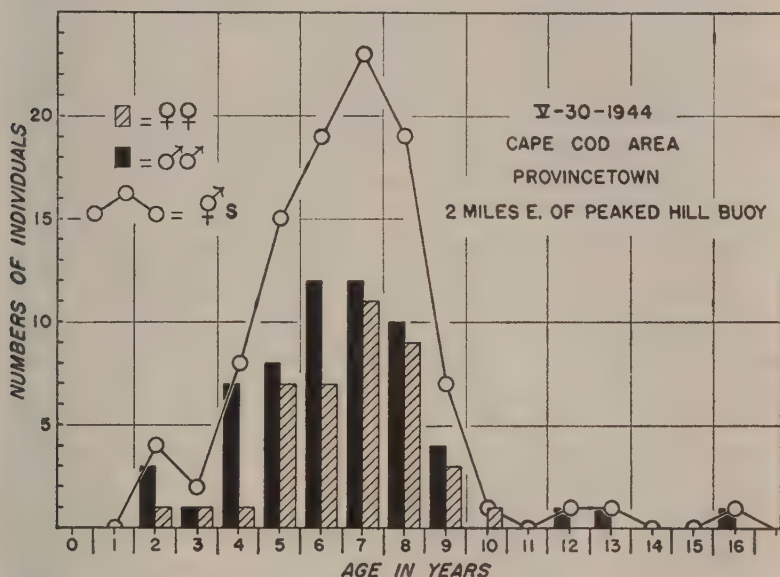


Figure 14. Age composition of a typical haul of ocean pout by a commercial trawler.

two independent analyses, especially considering the limited size of the samples. Fig. 13 shows the comparative average growth-rates from southern New England and the Bay of Fundy. Note that it takes the northern fish seven years to attain a length of 40 cm. while the southern fish reach the same length in four years, and that northern ocean pout average approximately 12 years old at 60 cm., while southern individuals attain a similar length in six and one-half years. Note also that the northern fish apparently do not reach as great a length as the southern ones, the upper limit in the former being 70-75 cm., while in the latter it is well over 90 cm.; however, larger samples from the north might alter this impression.

Finally, Fig. 14 shows the age composition of a typical commercial catch in southern New England, in which the four- to 10-year-old fish make up the great majority of the haul. Further discussion of this material appears in the following section.

AGE AT MATURITY

Since no spawning populations of ocean pout were available for study because this species does not appear in the commercial catch in September and October, except as occasional strays, it was impossible to determine the age at maturity from direct observation. The only previous studies on the age at maturity are those of Clemens and Clemens (1921), who stated that "... the fish do not become sexually mature until they have attained a length of about 40 to 45 cm.," at which time, according to their age estimates, Bay of Fundy ocean pout would be about eight years old.

The first method used in our attempts to establish the age at maturity involved the study of sections of 42 gonads from fish of different sizes taken at various times during the year from the southern New England area (Fig. 16). The results of the study of the ovaries provided a general indication that approximately 50 per cent of the 54.5–57.0 cm. female ocean pout were mature in the sense that they were apparently going to spawn in the following season. The criteria used in establishing approaching maturity were those which have been observed in other species by Hann (1927), Bullough (1939), and Merri-man and Schedl (1941). These included especially the increase in diameter of eggs, the differential staining properties, and the marked changes in degree and type of vacuolization of the yolk as shown in Fig. 16 E, F, G and H. According to the evidence derived from these observations, roughly half of the females in the population are mature in their sixth or seventh year of life. The results of the study of the testes indicated that all the male ocean pout below 25 cm. were immature, while above 39 cm. nearly all were mature, although one individual at 57 cm. appeared not to have reached maturity. The criteria for establishing approaching maturity—*i. e.*, the fact that the fish would spawn in the next season—were the relative number of cells in the different spermatogenic stages and the gross arrangement of the sex cells in either a compact (Fig. 16A) or a more diffuse, radial (Fig. 16B, C, D) manner. The majority of males examined were from the May 30, 1944, collections, which were the largest samples taken nearest to the time of the spawning season. Individuals judged to be immature showed a predominance of spermatagonia with occasional primary spermatocytes, while those which were apparently maturing had secondary spermatocytes, spermatids and, in one instance, a few sperma-



Figure 15. *A.* Lateral view of the right otolith (sacculith or sagitta) from a 1+ ocean pout 18.5 cm. long taken June 1944. Magnification $\times 24.7$. *B.* The same view of the right otolith from a 16+ individual 93.5 cm. long taken May 30, 1944. Magnification $\times 16.3$. *C.* Caudal vertebrae and associated rays stained by Alizarin Red S after the method of Cumley, Crow and Griffen (1939).

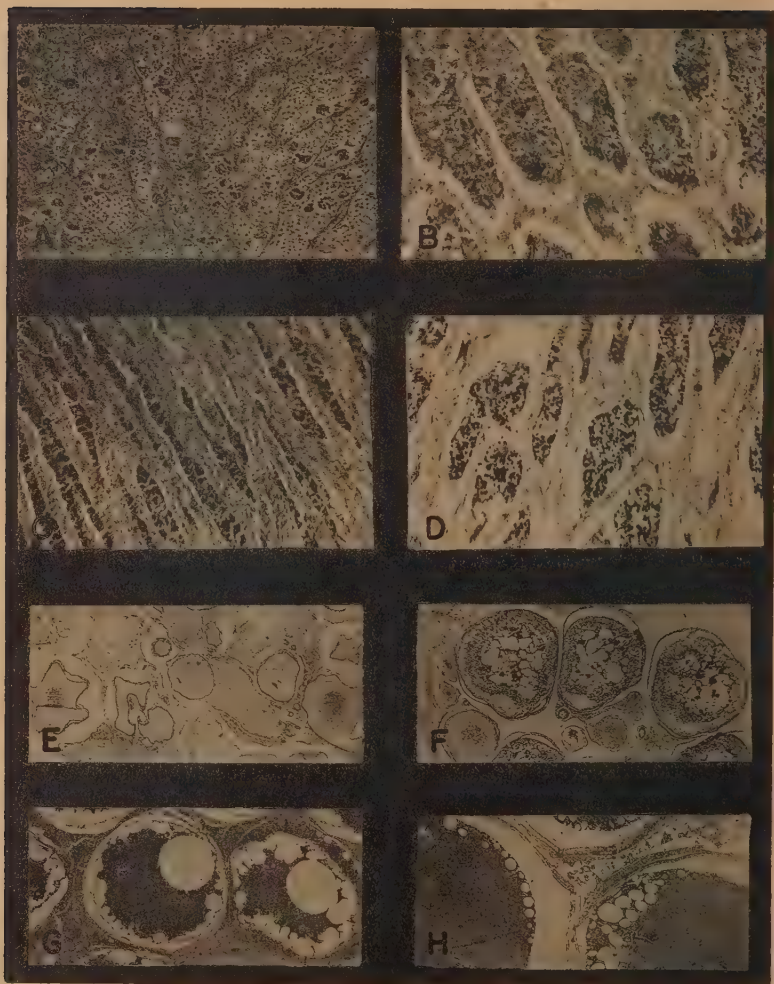


Figure 16. Sections of testes and ovaries of the ocean pout. *A.* Immature male; 26.5 cm.; June 1944. *B.* Mature male; 52 cm.; May 30, 1944. *C.* Mature male; 56 cm.; April 6, 1944. *D.* Mature male; 57 cm.; April 22, 1943. *E.* Immature female; 55 cm.; Aug. 7, 1943. *F.* Mature female; 55.5 cm.; April 22, 1943. *G.* Mature female; 54.5 cm.; April 23, 1944. *H.* Mature female; 54.5 cm.; Sept. 9, 1943.

tozoa. On the basis of this distinction, which agreed well with the gross appearance of the testis (compact or more diffuse distribution of the sex cells), roughly half of the males are probably mature in their third year of life and the great majority are mature in their fourth year, although some apparently do not mature until they are five or more years old.

Another possible means of determining the age at maturity lies in the estimation of the percentage of weight of the fish occupied by the weight of the gonads. These data must be available over the greater part of the size-range of the population at a single date; if the gonads have increased in size in preparation for spawning in the season to come so that the change can be detected, they should provide an indication of the approximate length at maturity. The gonads of those individuals which are not maturing should show a relatively low percentage value, while the ovaries or testes of those that are going to spawn in the coming season should have a higher percentage value, the degree of difference depending on the proximity to the spawning season. For this purpose we have used the three large collections of May 30, 1944 (Table VIII, Fig. 17). Comparison of the data from Block Island Sound, Muskeget Channel and Provincetown indicate slight differences in these three localities, but there is no consistent trend that can be taken as evidence that the ages at maturity in the regions within the general southern New England area differ. It is more probable that these differences are indicative of the normal variation within the species, and the results from the three localities have therefore been averaged together to give the figures on which Fig. 17 is based. It is also probable that the method of weighing the gonads¹ resulted in slight inconsistencies, since it is difficult to weigh each in an exactly comparable manner due to variations in the amount of fluid, extraneous tissue, *etc.*; but these differences were so small as to be of little or no significance in the analysis of the material. From Fig. 17 it becomes obvious that below 40 cm. the values for the females were consistently low, indicating immaturity up to this length. From 40–69 cm. the values show a progressive and rather sharp increase, with

¹ The fish were weighed fresh and the gonads were preserved in formalin and weighed at a later date. The percentage values in Table VIII and Fig. 17 are therefore probably not accurate indications of the true relationship of gonad to fish. But since the method of procedure was always the same, the validity of the data for the determination of length and age at maturity was not impaired.

TABLE VIII. AVERAGE PERCENTAGE WEIGHT OF GONADS (WEIGHT OF GONAD DIVIDED BY WEIGHT OF FISH) AT 5-CM. INTERVALS
BASED ON COLLECTIONS FROM THREE LOCALITIES ON MAY 30, 1944

Block Island				Muskeget Channel				Provincetown				Summary			
Average Length (Cm.)	Number of Specimens	Aver. % Weight of Gonads		Average Length (Cm.)	Number of Specimens	Aver. % Weight of Gonads		Average Length (Cm.)	Number of Specimens	Aver. % Weight of Gonads		Average Length (Cm.)	Number of Specimens	Aver. % Weight of Gonads	
38.6	♂ 1	0.120		....	♂ ..	.....		39.1	♂ 2	0.083		39.0	♂ 3	0.095	
45.2	6	0.098		....	..	.....		44.9	5	0.093		45.1	11	0.095	
50.1	7	0.100		50.7	5	0.106		50.2	7	0.089		50.3	19	0.097	
54.9	7	0.150		55.9	5	0.124		54.8	13	0.116		55.0	25	0.127	
60.1	9	0.152		59.5	9	0.124		60.2	8	0.117		59.9	26	0.131	
64.4	10	0.152		65.3	5	0.145		65.0	8	0.155		64.7	23	0.152	
69.9	8	0.152		70.1	1	0.170		69.0	3	0.167		69.7	12	0.158	
74.0	1	0.210		....	..	.....		74.4	3	0.173		74.3	4	0.182	
....	..	....		....	..	.....		79.2	2	0.200		79.2	2	0.200	
....	..	....		....	..	.....		85.1	2	0.260		85.1	2	0.260	
....	..	....		....	..	.....		93.7	2	0.270		93.7	2	0.270	
....	♀	....		....	♀	....		26.4	♀	0.070		26.4	♀	0.070	
....	..	....		....	..	....		30.0	1	0.100		30.0	1	0.100	
39.5	1	0.190		....	..	....		39.9	2	0.130		39.8	3	0.150	
44.4	2	0.765		....	..	....		42.5	1	0.140		43.8	3	0.557	
50.0	8	0.920		....	..	....		49.8	4	0.570		49.9	12	0.801	
55.3	12	1.750		55.1	11	1.420		54.5	11	0.940		55.0	34	1.380	
59.7	22	1.900		60.1	15	1.830		58.5	5	1.118		59.8	42	1.625	
64.0	8	1.540		64.4	15	1.720		64.1	6	3.200		64.2	29	1.980	
....	..	....		68.4	5	2.400		69.9	5	3.900		69.1	10	3.150	
....	..	....		....	..	....		76.2	1	3.100		76.2	1	3.100	

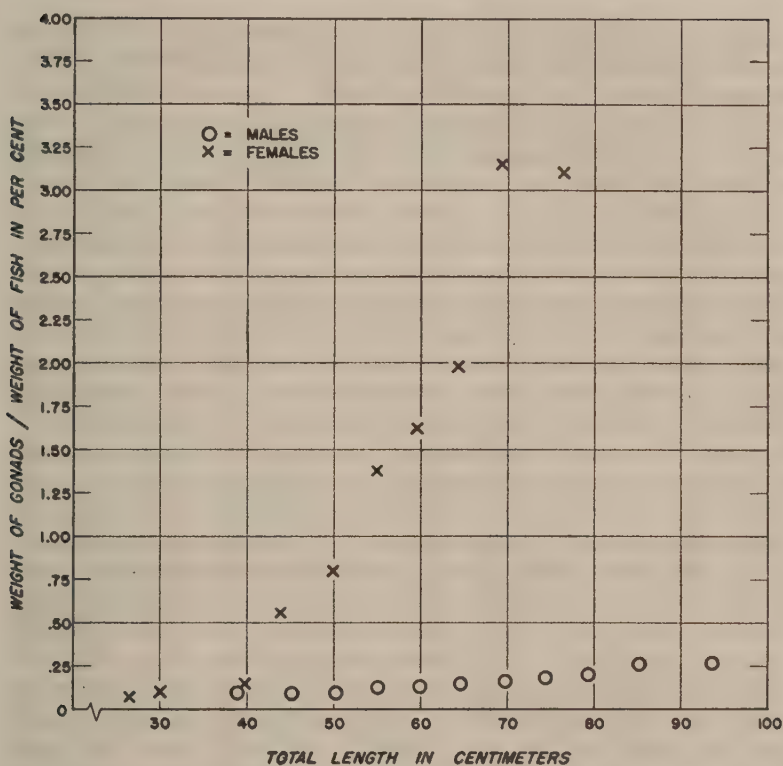


Figure 17. Average values for the percentage of the weight of the fish occupied by the weight of the gonad plotted against length (5-cm. intervals). Data based on the collections of May 30, 1944, from three localities in the southern New England area. See text and Table VIII.

a tendency to level off above 69 cm. This indicates that females first become mature at approximately 45 cm. (in their 5th and 6th year of life), and that all of them are mature at 69 cm. (in their 8th and 9th year of life). It also bears out the conclusion drawn from the study of the sectioned material that approximately 50 per cent of the females are mature by the time they reach the 55-60-cm. interval. However, the data on the males give no clear indication of the age at maturity; the values are consistently low from 39-94 cm., although they do show a gradual tendency to increase over this range. There are two reasons why the curve for the males does not show a definite "break" or sharp

change in percentage values. First, the increase in size of the testis in maturing individuals does not take place as far ahead of the spawning season as does the increase in the ovary. Since the collections on which these data are based were made approximately four months ahead of the spawning season, it was to be expected that the increase in size of the testes would not yet be manifest. Second, if the conclusions drawn from the examination of sectioned material are correct, and if nearly all males above 39 cm. are mature, the individuals providing the present data were all too large to give information on the length and age at maturity. Finally, note that the tendency toward an increasing *percentage* of the weight of the fish occupied by the weight of the gonad in *mature* individuals (indicated previously, pp. 71-73) is evident from Table VIII and Fig. 17. This is particularly true with the males, but shows also in the females. If this phenomenon be accepted as fact in the females, it alters our estimates as to the length at which all female ocean pout are mature. Thus the two points at 69 and 76 cm. may be interpreted as being so high because of this phenomenon rather than because all the females are mature only by the time they reach 69 cm. Under the circumstances it seems reasonable to lower the length at which all of the females in the population are mature to 65 cm. (probably their 7th to 9th years of life).

Still another means of determining the age at maturity of the females is provided by comparative egg measurements from individuals over a wide size-range at a period approaching the spawning season. For this purpose also we used the three collections of May 30, 1944, because they were the last large samples available before spawning. Even though spawning was still four months away at this period, the eggs which were developing for reproduction in the fall were large and conspicuous as opposed to those that were being held in reserve for subsequent spawning seasons. Usually there was also a marked difference in color, appearance and structure between the maturing and immature eggs as indicated previously (p. 69). However, some ovaries contained eggs of intermediate size, so that it was impossible at this period to be certain whether or not they were eggs which were maturing for the approaching spawning season. Table IX shows the average diameters¹ resulting from measurements of 25 eggs from each of the ovaries of females from 42.5-76 cm. in length; these fish were taken in Block Island Sound, Muskeget Channel, and off Provincetown on

¹ Chain series of five and ten eggs were lined up and measured by dividers.

TABLE IX. RANGE IN SIZE OF OVA FROM INDIVIDUAL OCEAN POUT TAKEN FROM THREE LOCALITIES ON MAY 30, 1944. 25 EGGS FROM EACH OVARY MEASURED.

Block Island				Muskeget Channel				Provincetown			
Total Length (Cms.)	Total Weight (Gms.)	Average Diameter of Eggs	Average Actual Size	Total Length (Cms.)	Total Weight (Gms.)	Average Diameter of Eggs	Average Actual Size	Total Length (Cms.)	Total Weight (Gms.)	Average Diameter of Eggs	Average Actual Size
42.8	367	1.22	●	...	...	...	...	42.5	277	0.98	●
46.0	525	2.37	●	...	...	...	...	46.0	377	1.24	●
47.5	590	2.80	●	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	48.5	523	1.51	●
49.0	637	1.84	●	49.5	622	1.97	●	...	...	...	...
50.0	749	2.23	●	50.0	645	2.26	●	50.0	657	2.36	●
51.5	700	1.81	●	...	...	...	...	52.0	680	1.52	●
52.0	801	3.06	●	52.5	873	2.43	●	53.0	708	1.25	●
53.0	788	1.84	●	53.0	852	2.46	●	53.0	782	2.70	●
53.2	998	2.64	●	...	...	...	...	53.5	789	1.48	●
...	...	...	...	53.5	963	2.94	●	...	...	...	...
54.0	927	2.45	●	54.0	848	1.72	●	...	...	...	...
54.8	1048	2.67	●	55.0	885	2.57	●	55.0	812	1.56	●
55.5	1225	3.12	●	55.5	994	1.65	●	...	...	...	...
56.0	1089	2.14	●	56.0	862	2.02	●	56.0	840	1.58	●
57.0	1247	2.22	●	56.5	1048	2.83	●	57.0	1089	3.56	●
57.3	1066	2.76	●	57.5	1048	2.80	●	57.5	918	2.55	●
57.7	1093	1.36	●	58.0	1093	3.28	●	...	...	...	...
58.0	1043	2.23	●	58.0	970	1.86	●	...	...	...	...
58.5	1188	2.04	●	58.5	1270	2.35	●	58.5	921	2.59	●
59.0	1252	2.66	●	59.0	1025	2.44	●	...	...	...	...
59.0	1225	1.94	●	59.0	1084	3.18	●	...	...	...	...
60.0	1157	2.55	●	60.0	1043	3.41	●	60.0	1139	2.56	●
60.5	1452	3.26	●	60.5	1225	2.00	●	60.5	1238	1.57	●
60.5	1270	2.13	●	60.5	1415	3.12	●	...	...	...	...
61.0	1452	2.80	●	61.0	1179	2.86	●	...	...	...	...
62.0	1492	2.52	●	62.0	1238	3.06	●	...	...	...	...
62.5	1270	2.14	●	62.5	1315	1.14	●	62.5	1270	3.80	●
...	...	...	...	63.0	1465	2.45	●	62.5	1870	3.58	●
63.5	1792	2.96	●	63.5	1510	4.16	●	...	...	...	...
64.0	1438	2.59	●	64.0	1510	3.23	●	...	...	...	...
64.0	1497	2.67	●	...	...	...	...	...	...	...	...
...	...	...	...	64.5	1551	3.01	●	64.5	1710	3.77	●
...	...	...	...	64.5	1497	2.48	●	64.5	1452	3.66	●
65.0	1633	2.40	●	65.0	1905	2.62	●	65.0	1874	3.77	●
65.0	1542	2.41	●	65.5	1606	2.76	●	65.5	1315	3.24	●
67.0	1796	2.85	●	66.5	1470	2.30	●	...	...	...	...
...	...	...	...	67.5	1733	3.43	●	...	...	...	...
...	...	...	...	68.5	1796	2.71	●	68.1	1769	3.33	●
...	...	...	...	69.0	2046	3.25	●	...	...	...	...
...	...	...	...	...	...	...	...	70.3	1803	3.44	●
...	...	...	...	...	...	...	...	72.0	2046	4.27	●
...	...	...	...	...	...	...	...	76.2	2508	3.70	●

May 30, 1944. Accompanying the lists of measurements are drawings to scale of the actual eggs (the average size of each sample of 25) in order to facilitate visual interpretation of the material. The eggs measured were, of course, from the larger size category in each ovary, provided a distinction could be made. It seems clear from Table IX that all females 63 cm. long or above were preparing to spawn that fall—*i. e.*, they were mature. Below that length an increasing number of immature individuals with small eggs are evident, particularly in the Provincetown collection, although it appears that some females in the 46–50-cm. interval had eggs in the process of preparation for release four months hence. A number of the eggs from fish in the general 45–60-cm. range were of indeterminate nature; they were of such a size that it was impossible to predict with certainty whether or not they were maturing for the oncoming spawning season. It is of interest that fewer female ocean pout below 63 cm. were mature in the Provincetown than in the Block Island and Muskeget Channel collections; it may be that a smaller proportion of the individuals in the 40–60-cm. group mature in northern Cape Cod waters than further to the south and west. The results of this analysis bear out the conclusions derived from other methods, namely that the first females to mature are approximately 45 cm. in length (4+ years old), and that all the females in the population are mature by the time they are approximately 65 cm. long (6–8+ years old). These data could also be taken to indicate that female ocean pout do not necessarily spawn every year, a possibility which Clemens and Clemens (1921) suggested. Thus the eggs of intermediate and indeterminate size could be construed as belonging to females, some of which had already spawned at least once, which were going to spawn some 16 months hence. It is impossible to settle this matter on the basis of the present material, and more adequate samples, preferably of the whole population at the time of spawning, would be necessary to answer the question.

One final source of information which can be used in attempts to estimate the average length and age at maturity of female ocean pout is derived from length-weight analyses of the separate sexes. The length-weight curve for the combined sexes, as well as the coefficient of regression, has been shown in Fig. 4, and a discussion of this subject appears on pages 42–45. The same data, with *separate* fitted curves and regression coefficients for each sex, are shown in Fig. 18. Note again that some 598 males and 516 females were used in the preparation of

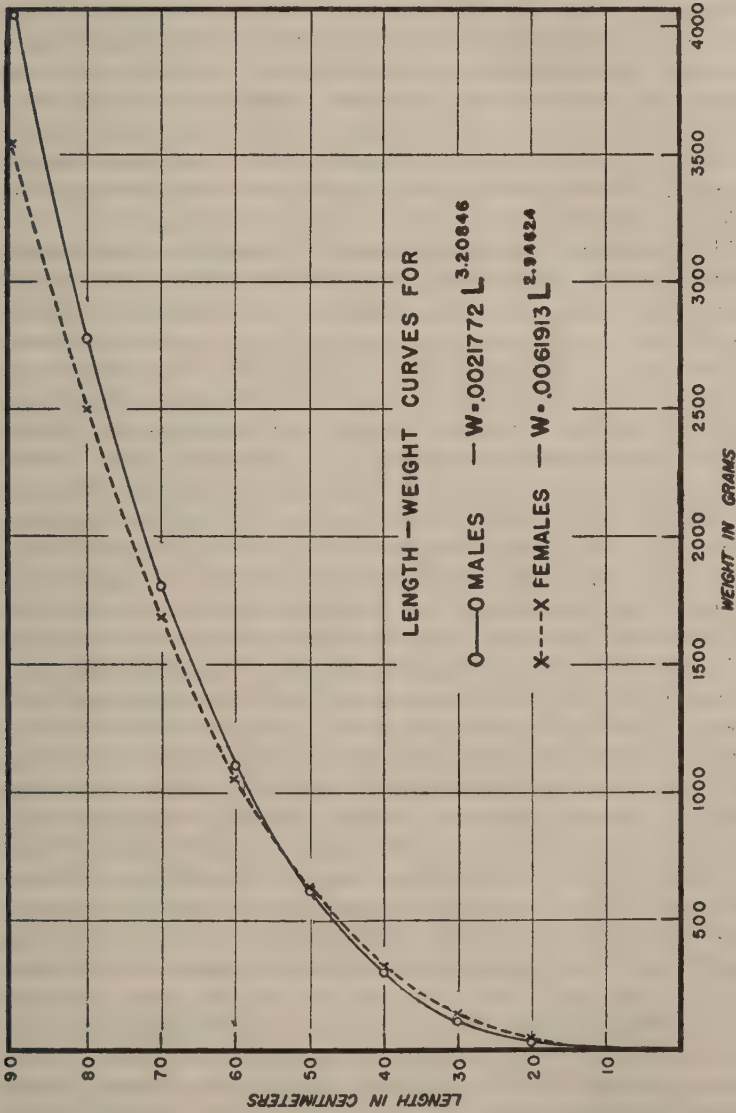


Figure 18. Regression curves showing the length-weight relationships of male and female ocean pout. See text for discussion.

each curve, and that the collections from which these data were taken were made over the period of a full year; therefore the weights represent as nearly as possible an average condition. It is of interest that below 55 cm. on the average the females apparently weigh somewhat more than the males of similar length. Conversely, at any length above 55 cm. the females weigh increasingly less than the corresponding males. The reason for this may perhaps be due to the gonadal differences between the two sexes; the point of crossing of the curves would thus indicate the average length at maturity of the females. Below 55 cm. the males tend to weigh less because they mature and spawn earlier in life. Over the period of a year some of their food is converted into testicular material, much of which is lost during spawning. However, in the majority of females below 55 cm. the food is converted into ovarian material which is not lost since they are not yet mature and do not spawn—that is, their conversion of food into gonadal tissue is, for the time being, on a permanent basis. Above 55 cm. the situation is reversed. The females weigh less than the males of the same length because by this time the great majority are mature. Thus, proportionately more food is converted into ovarian tissue and yolk material, due to the exceptionally large size of the gonad, than is converted into testicular tissue by the male; since this material is lost in the process of spawning, the average weight of the females over a full year is less than that of the corresponding males. Put in another way, the conversion of food into ovarian and yolk material in mature females is relatively much greater than the conversion of food into testicular material in mature males; since a large proportion of this gonadal material in both sexes is lost at spawning it follows that the gain in total weight of the fish over the period of a year is, on the average, less in the female than in the male. However, another reason for the greater weight of the males at the larger sizes might lie in the greater size of the relatively larger head. And a further explanation of the lower average weight of the mature females might be that they do not feed as much as the males during the reproductive season; but if this were true they probably would not grow quite as fast as the males, so that a comparison of weights at comparable lengths should not show any differences; moreover, there appears to be no great differential in the growth rates of the two sexes. Therefore it seems quite likely that the explanation lies in the gonadal differences between the two sexes. The fact that the crossing of the

two length-weight curves occurs at the point which represents the average length at which maturity is attained by the females (55 cm.) as determined by all *other* methods at our disposal lends strength to the validity of this interpretation. It is of interest in this connection that Thompson (1942), in his discussion of the "ponderal index" or weight-length coefficient, used the changes in k (where $W = kL^3$) at different lengths of the plaice to determine the size at sexual maturity. He further pointed out that, "A step towards further investigation would be to determine k for the two sexes separately, . . ." and cites the work of d'Ancona (1928) who has done this for the shad (*Alosa finta*).

SEX RATIOS AND SEASONAL MOVEMENTS

Studies on the sex ratios of ocean pout in the available samples, which were almost entirely from the commercial catch, are subject to error from the inadequacy of the sampling of the population in somewhat the same way as the length-frequency curves discussed previously (p. 83). With certain exceptions (see below), however, the trawl net is probably not seriously selective for sex. While it is highly selective for size, those ocean pout which could escape through the mesh but which happen to be taken in the trawl net are probably the result of pure chance so that their sex ratios should not be distorted. In other words, these small fish are only caught at all because the cod-end becomes so full that means of escape through the mesh is partially blocked; these small individuals, if taken in sufficient quantities, should offer adequate sex-ratio data. But at certain sizes (in the 50-60-cm. interval) there is good evidence that the gear *is* selective for sex (p. 85). We need only repeat here that more females than males of this length are retained in the net because their ovaries are sufficiently distended in the spring months to make them bigger enough around so that they do not escape as easily as males of a corresponding length. Thus the peak of female preponderance at the 55-60-cm. interval in Fig. 19 is, in all probability, due to the selectivity of the gear.

The data for sex ratios at 5-cm. intervals in ocean pout from 30-90 cm., as plotted in Fig. 19, seem to indicate a fairly general preponderance of males. Eliminating the major peak of females in the middle of the graph on the basis of selectivity of the gear, there remains only one point at which there are more females than males. This is in the

30-35-cm. interval and the sample includes but 13 individuals (6 males and 7 females); obviously the numbers involved are inadequate. Therefore, it seems most reasonable to assume a slight preponderance of males over females throughout the majority of the life of this species. This preponderance apparently increases at the larger size categories, although the data on this point are limited. This fact is also apparent from Fig. 4, where it is obvious that the males make up the major part

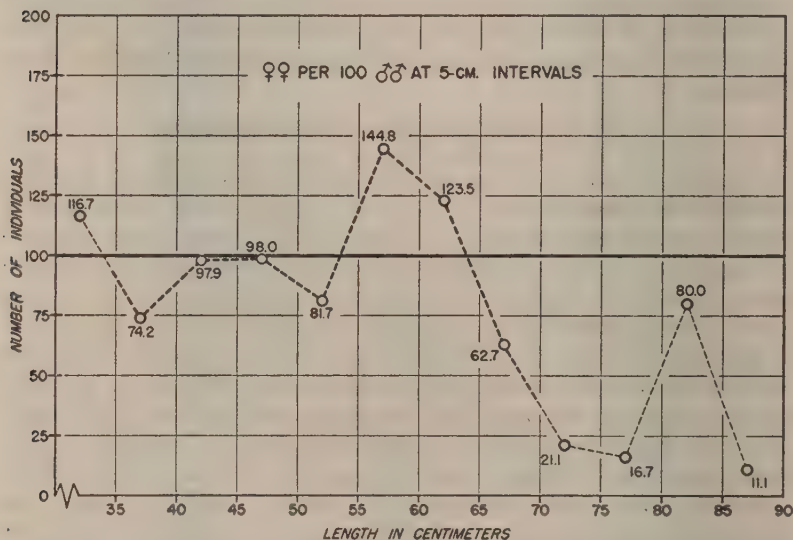


Figure 19. Sex ratios at 5-cm. intervals from 30-90 cm., as indicated by number of females per 100 males. Data based on collections of approximately 1100 ocean pout from southern New England over a complete year from April 1943 to April 1944. Points connected by light broken line involve a total of less than 50 specimens. See text for further discussion.

of the upper limits of the length-weight curve. Even granting that the last four points in Fig. 19 are made up of a total of only 93 individuals, the trend is so consistent as to leave little doubt that there are actually more males than females in the largest size groups of the population. The explanation of this could lie in a faster and greater growth by males, so that if death occurred at approximately equal rates for both sexes over the age-span, the largest individuals of the population would usually be males. But while there is some hint that the males may grow slightly faster than the females (p. 91), it does

not seem likely that this is sufficient to produce the end result here indicated. More probably the explanation lies in the simple fact that as a general rule the males live longer than the females. Note that the collections for the data in Fig. 19 were made over a full year in an effort to eliminate any seasonal effects, such as the separate migration of sexes, which might produce a wholly false picture of the true sex ratio of the total population. Ideally for this purpose large samples of equal size should be collected at fairly frequent intervals. Unfortunately this was impossible since the ocean pout is taken by the commercial fishery only from December to June. The majority of our data is derived from the winter and spring months, although some small collections were made in the summer and fall (Table V). However, the sampling in point of time is probably sufficiently accurate to validate the conclusions outlined above.

The analysis of the sex ratios of the population of ocean pout in different regions at different times of year is shown in Fig. 20 and Table X. These data are based on samples which of course included fish from the 45–60-cm. interval, so that if the net is selective for sex as indicated above, the figures derived are unduly weighted on the female side of the population as a whole. The precise amount of distortion obviously depends on the proportion of individuals in each sample which fall between roughly 45 and 60 cm. It is possible, therefore, that the dominance of females at four points in the Block Island Sound area sex ratios in Fig. 20 is not a true representation of the condition in the population. Similarly, the preponderance of females in the May collection from southern Cape Cod is probably not a fair indication of the sex ratio of the population at that time. It is significant in this connection that all the collections in which female dominance occurs were taken at a time of year when the ovary had attained a relatively large size and might make the females just enough bigger around so that individuals of the proper size would be retained by the net, while males of corresponding lengths would escape (p. 105). However, where there is a dominance of males there can be no question that individuals of this sex are more abundant than the females, although it may well be that, due to the selective nature of the gear, the data presented in Fig. 20 and Table X do not indicate the proper *extent* of male dominance. It is of interest that the males are predominant in the December and January samples—particularly so at the former date. This is the time of year at which ocean pout first

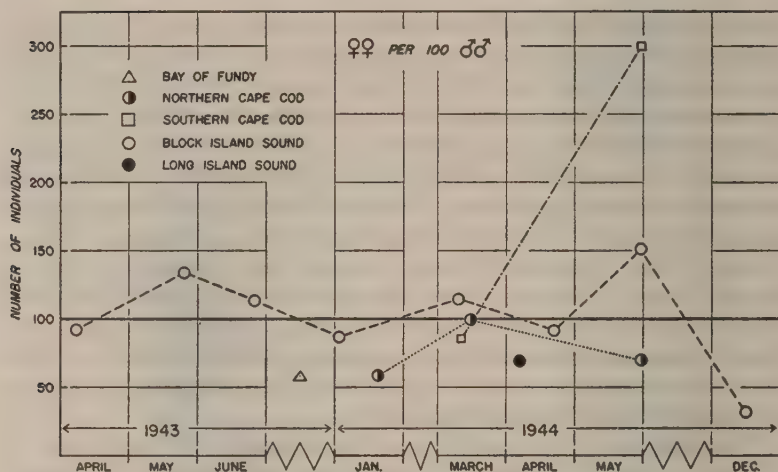


Figure 20. Sex ratios of ocean pout in the commercial catch by months in 1943 and 1944 expressed as number of females per 100 males. All samples involve 50 or more specimens, with the exception of the mid-March collection of 44 individuals from Block Island Sound. See Table X.

appear in the commercial catch, and a period during which they apparently migrate from the rocky areas in which they have spent the preceding summer and fall and have spawned. It thus appears that the males leave the rocky habitat first and are shortly followed by the females. White (1939) pointed to the possibility that both parents protect the developing eggs (p. 68). According to our estimates, hatching in southern New England waters occurs in December; the departure of the males from the rocky bottom probably coincides with the late egg and early larval stage of the embryos, which would indicate that the males, if indeed they do have any role in protecting the eggs, abandon their parental duties before the females do. In all events there seems to be little doubt that the males leave the rocky areas shortly before most of the females and therefore appear on the grounds worked by the commercial trawlers first. Conversely, there is some indication that the males leave the smoother areas and return to the rocky habitat first in May and June. Fig. 20 shows the dominance of females in two out of three of the May 1944 collections, as well as in the June 1943 sample. The extreme in female dominance was in the collection of May 30, 1944, from southern Cape Cod, where there

TABLE X. NUMBER OF MALE AND FEMALE *Macrozoarces americanus* IN DIFFERENT SAMPLES FROM VARIOUS LOCALITIES IN 1943 AND 1944

Locality	Date	♂♂	♀♀	Total ♀♀ per 100 ♂♂
<i>BAY OF FUNDY:</i>				
Within 5 mi. of St. Andrews, New Brunswick.	June 15 to Oct. 25, 1943.	63.	37.	100. 58.7
<i>NORTHERN CAPE COD</i>				
10 mi. SW. of Wood End Light.	Jan. 20, 1944.	95.	56.	151. 59.0
8 mi. NNW. of Race Pt. Light.	Mar. 15, 1944.	36.	36.	72. 100.0
2 mi. E. of Peaked Hill Buoy.	May 30, 1944.	60.	42.	102. 70.0
<i>SOUTHERN CAPE COD</i>				
Nantucket Shoals, 40° 55' N., 69° 35' W.	Mar. 10-13, 1944.	28.	24.	52. 85.8
8 mi. SW. of entrance to Muskeget Channel.	May 30, 1944.	26.	78.	104. 300.0
<i>BLOCK ISLAND SOUND:</i>				
2½-4 mi. off Watch Hill, R. I.	Apr. 7, 1943.	26.	24.	50. 92.4
2½ mi. NNE. of Block Island.	May 25, 1943.	32.	43.	75. 134.3
2½ mi. NNE. of Block Island.	June 15, 1943.	30.	34.	64. 113.3
Old Harbor, Block Island.	Jan. 2, 1944.	70.	61.	131. 87.2
5 mi. SW. of Block Island.	Mar. 12, 1944.	76.	87.	163. 114.5
3 mi. S. x E. of Watch Hill, R. I.	Apr. 19-23, 1944.	23.	21.	44. 91.3
3-4 mi. ENE. of Block Island.	May 30, 1944.	49.	74.	123. 151.0
2 mi. S. of Charlestown Inlet, R. I.	Dec. 18, 1944.	44.	14.	58. 31.8
<i>LONG ISLAND SOUND:</i>				
3½ mi. N. of Pt. Herod, N. Y.	Apr. 6, 1944.	88.	61.	149. 69.4

were three times as many females as males. However, the conclusion that the males lead the way in returning to the rocky habitat in the spring does not rest on secure evidence. Quite apart from the previously indicated error in sampling the different sexes, note that the collection of May 30, 1944, from northern Cape Cod had a dominance of males. The hypothesis that the males leave for the summer and fall rocky habitat first therefore needs confirming evidence. On the other hand, the movement of the males from the areas of spawning and early development in the winter is more firmly established, although additional data would be necessary to settle the regularity and extent of this trend.

Both in the present section and elsewhere (pp. 39-42, 115) we have provided evidence to show that the general pattern of the movements of the ocean pout is seasonal. In southern New England waters this species appears in the catch of trawlers which work on relatively smooth bottom at depths of from 10-30 fathoms in late December and January; in the late spring (May and June) it essentially disappears from the catch, probably returning to rocky areas mostly within the 30-fathom contour for the period from June to December. The question now arises as to the extent and magnitude of these movements. Do they include the entire population or do they involve only the fish above a certain size and age? This is a point on which we have little information, for the trawl nets by which most of our collections were made were of such large mesh that they took relatively few small individuals. It is very seldom that ocean pout below 25-30 cm. are taken by such gear, but fish of this size and age (2+ and 3+ groups) are taken often enough to justify the conclusion that at least some of them are involved in the movements of the larger individuals. The capture of the smallest fish (0+ and 1+ groups) is so rare as to indicate that they probably do not, for the most part at least, take part in the movements of the larger elements of the population. If these young fish were present in large quantities they would be taken far more commonly than is actually the case, and they would almost certainly be found in the stomach contents of sculpins (*Myoxocephalus octodecimspinosus*) and angler fish (*Lophius americanus*¹) taken in these hauls. Both of these fish, which are excellent living "bottom samplers," have been examined in detail in considerable numbers, but

¹ See Bigelow and Schroeder (1936) for the use of the specific name *americanus* as opposed to *piscatorius*.

neither of them have yielded a single ocean pout, although the rather closely related rock eel, *Pholis gunnellus*, has been recovered from them on several occasions. Thus, the almost complete absence of small ocean pout from the catch of the trawl net (which takes comparably small whiting, hakes, etc. rather profusely at certain seasons) and the failure to find them in the stomachs of sculpins or anglers provides evidence for believing that these small individuals are only present in limited numbers on the commercially trawled smooth bottom as strays from a more rocky habitat. Probably the majority of 0+ and 1+ fish, some 2+ and possibly older individuals, do not take part in the typical seasonal movements of the larger ocean pout. After the completion of the third year, however, great numbers of ocean pout undertake these movements, although it is impossible to say whether or not the total "adult" stock is involved, or what proportion, if any, remains in the rocky habitat on a year-round basis.

RACIAL ANALYSES

Racial studies on the American ocean pout should be of particular interest because of the classical work of Schmidt (1917a, b, 1918, 1920, 1921a, b) and Smith (1921, 1922) on the European *Zoarces viviparus*, as well as the more general studies of Hubbs (1922, 1924, 1926, 1934) and others on racial and individual variations in fishes. Probably the most concise statement of these researches is that of Hubbs (1934), who stated:

The most extensive and best known race investigations with fishes are those of Johannes Schmidt (1917 to 1930) on *Zoarces* and other fishes . . . Schmidt's results are too well known to require much review. The analysis of thousands of specimens of *Zoarces* showed that this relatively stationary fish exhibits marked local variations, which are inherited though slightly modifiable; that the variations are correlated with hydrographic conditions, but not perfectly so correlated; and that the variations show annual fluctuations. Schmidt also obtained valuable results with individual modifications and inheritance in *Lebistes* and *Salmo*. In a more recent work (1930), a masterly investigation on the variation of the cod in the North Atlantic showed so strikingly the correlation of structural characters with water temperatures that the author placed more emphasis on this correlation than previously. In his *Zoarces* investigation, Schmidt made a rather strained effort to minimize the relation of the environment to the racial characters.

. . . in my laboratory, we have stressed geographic and climatic trends in variation; parallel raiation; the correlation between rate of development and meristic characters; the probably indirect, adaptive significance of most

racial distinctions; the parallel but presumably unrelated racial and individual modifications, especially those determined by temperature acting during development; the great modification of characters by such factors as early parasitization and siltiness of water . . .

. . . Signs are not lacking that the study of variation in fishes and other animals is being rejuvenated into a live division of zoology. This study may well assume such a position, if it is prosecuted not as an end in itself, but as a tool to be used in solving problems in systematics, economic zoology, zoogeography and evolution.

As the various samples of ocean pout came to the laboratory, it was a routine part of the analysis to count the vertebrae. The flesh was filleted off one side so that the vertebral column was exposed, and counts were usually made without the aid of magnification, although it was easier to enumerate the last 10 or 15 caudal vertebrae with the help of powerful illumination from the uncleaned side of the fish. It was readily apparent on inspection of the data that the counts from any particular region were inaccurate at first; they showed consistent trends toward a more regular pattern as the accuracy of counting increased, and all the accumulated material before the attainment of constancy was therefore eliminated. Nevertheless, the number of vertebrae on which Fig. 21 and Table XI are based is 128,356. It is not surprising that inaccuracies in counting occur at first, for the difficulty is great because of the large number of vertebrae (131-144) and their relatively small size. In order to insure accuracy and constancy, one person did the vast majority of the counting. The hypural (Fig. 15C) was included throughout, and individuals with fused vertebrae (not uncommon) were noted but not included in the final analysis. Careful study of the data showed no consistent or significant difference between the individuals at the lower end of the length range and those at the intermediate and upper limits of size. Comparison of the counts in male and female individuals also showed no significant differences.

The summarization of the data in Fig. 21 and Table XIA and B shows that within the area studied it is possible to demonstrate significant differences in the vertebral counts of individuals from different localities. The right hand side of Fig. 21 shows the summaries of the frequency distribution of the vertebral counts from samples of ocean pout from five major regions—the Bay of Fundy, northern Cape Cod, southern Cape Cod, Block Island, and Long Island Sound. Table XIB shows the means and other pertinent data on the same material. The details of the individual samples are shown in the smaller frequency distributions on the left side of Fig. 21 and in Table XIA.

TABLE XI A. MEAN VERTEBRAL COUNTS AND NUMBERS OF INDIVIDUALS IN SAMPLES OF OCEAN POUT FROM DIFFERENT LOCALITIES. LETTERS BEFORE EACH AREA CORRESPOND TO THOSE IN FIG. 21. FOR RANGE IN VALUES SEE FIG. 21. NUMBERS IN PARENTHESES AFTER MAJOR AREAS CORRESPOND WITH THOSE SHOWN IN FIG. 3.

Locality	Date	♂ ♂		♀ ♀		♂ ♂ and ♀ ♀	
		No.	Mean	No.	Mean	No.	Mean
BAY OF FUNDY:							
Near St. Andrews, N. B.	VI-15 to X-25-1943	60	134.25	32	134.84	92	134.46
NORTHERN CAPE COD (8, 9):							
A. 10 mi. SW. of Wood End Light.	I-20-1944	56	139.80	32	139.19	88	139.58
B. 8 mi. NNW. of Racepoint Light.	III-15-1944	35	140.09	35	140.26	70	140.17
C. 2 mi. E. of Peaked Hill Buoy.	V-30-1944	55	140.91	42	141.00	97	140.95
SOUTHERN CAPE COD (6, 7):							
D. Nantucket Shoals 40° 55' N., 69° 35' W.	III-10 to 13-1944	27	140.11	23	140.48	50	140.28
E. 8 mi. SW. of Muskeget Channel.	V-30-1944	26	137.77	77	138.10	103	138.02
BLOCK ISLAND (3, 4, 5):							
F. ½ mi. SE. of Block Island.	I-2-1944	67	137.97	60	138.30	127	138.13
G. 5 mi. SW. of Block Island.	III-12-1944	72	138.07	86	138.00	158	138.03
H. 3-4 mi. ENE. of Block Island.	V-30-1944	46	137.74	70	138.70	116	138.32
LONG ISLAND SOUND (1):							
3 mi. N. of Pt. Herod, L. I.	IV-6-1944	83	136.28	59	135.88	142	136.11

TABLE XI B. SUMMARY OF VERTEBRAL COUNTS OF FISH FROM MAJOR AREAS. SEE RIGHT HAND SIDE OF FIG. 21

Major Area	♂ ♂		♀ ♀		♂ ♂ and ♀ ♀		Deviation
	No.	Mean	No.	Mean	No.	Mean	
Bay of Fundy	60	134.25	32	134.84	92	134.46	±0.145
Northern Cape Cod	146	140.29	109	140.23	255	140.25	±0.079
Southern Cape Cod	53	138.96	100	138.65	153	138.76	±0.123
Block Island	185	137.95	216	138.31	401	138.14	±0.055
Long Island Sound	83	136.28	59	135.88	142	136.11	±0.110

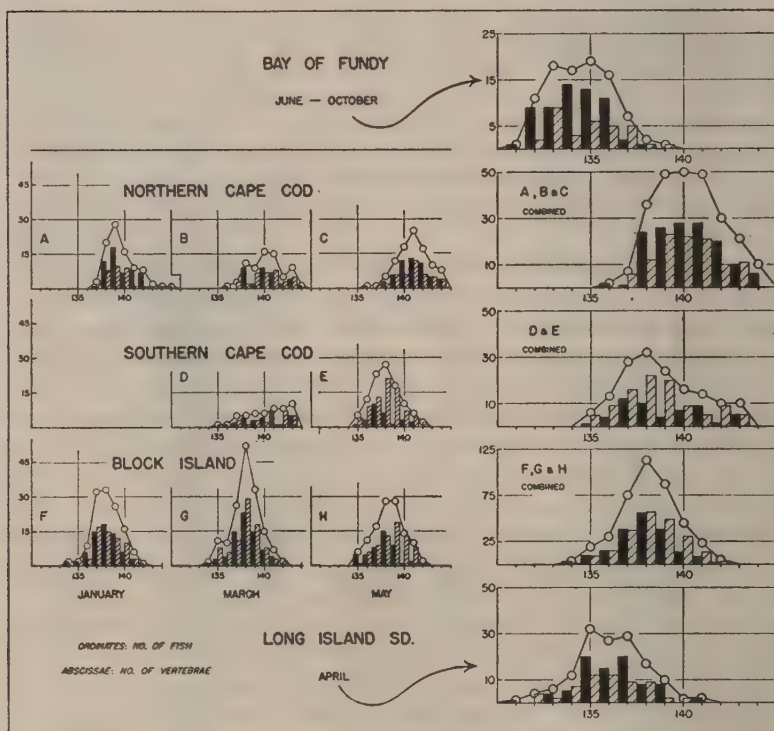


Figure 21. Frequency distributions of the vertebral counts of ocean pout from different localities. Black columns represent males, diagonally lined columns females, and the circles connected by lines are the totals of both sexes. Right side of graph shows the summarization of the data from the Bay of Fundy, northern Cape Cod, southern Cape Cod, Block Island, and Long Island Sound in that order reading down. The frequency distribution of the individual samples is shown in the smaller graphs on the left. See also text and Table XI A and B.

Note in Fig. 21, that with the exception of the sample from the Bay of Fundy, the summaries of the frequency distribution of the vertebral counts (reading from north to south) show a steady trend towards progressively lower levels. The sample from northern Cape Cod has a peak at 140 (mean 140.25), that from southern Cape Cod 138 (mean 138.76) with the curve skewed heavily to the right, that from Block Island 138 (mean 138.14) with the curve "normal," and that from Long Island Sound 135 (mean 136.11). The application of standard

significance tests to these data indicates that the populations from northern Cape Cod are distinct from those of southern Cape Cod as regards vertebral count $\left(\frac{d}{\sigma d} = 7.6\right)$, that those from southern Cape Cod and Block Island probably show some intergradation, although they tend towards being distinct $\left(\frac{d}{\sigma d} = 3.6\right)$, and that those from Block Island and Long Island Sound are clearly different populations $\left(\frac{d}{\sigma d} = 12.5\right)$. It is of considerable interest that the Long Island Sound population is so distinct from the others. Ocean pout from this region are apparently much smaller on the average than those from other areas (Fig. 11F), a fact which was noted by DeKay (1842) and Linsley (1844), and which led these naturalists to consider these fish a different species (*Z. fimbriatus*). The general decrease in the number of vertebrae in the samples from northern Cape Cod to Long Island Sound is in all probability a reflection of slightly and progressively higher temperature conditions from north to south and west over this range during the fall and early winter months when spawning and early development occur. It is also a clear indication that relatively little coastwise migration occurs in the southern New England area. Rather, it seems that ocean pout move to and from their summer and fall rocky habitat (pp. 40, 110) within somewhat limited and circumscribed regions. The entire life history of this fish is apparently spent in the same general area, and there is relatively little interchange even between closely approximating regions. Within the four localities under discussion, the northern Cape Cod and the Long Island Sound regions are clearly distinct from the two intermediate areas (southern Cape Cod and Block Island); within the latter two regions there is probably some intermixture.

The sample from the Bay of Fundy is of particular interest. If temperature alone were the controlling factor in the number of vertebrae, the vertebral counts should be highest in fish from this area.¹ Actually they are lowest, with a mean of 134.46. There are two pos-

¹ The data of Clemens and Clemens (1921) and White (1939) indicate that the bottom temperature in the Bay of Fundy drops fairly rapidly from approximately 10° C. in mid-September to low levels (0° C.) by January. Our own data (Table V), as well as that of Bigelow (1933), show that the decline in bottom temperature over the same period in southern New England is in no way so rapid.

sible alternative explanations for this. The first could lie in the fact that the gradation of meristic counts from high (at low temperatures) to low (at high temperatures) only occurs within certain thermal limits, and that below and perhaps above this range in the American ocean pout the number of vertebrae is extremely low. But this hypothesis would be at variance with the findings of Schmidt (1921a) for *Salmo trutta*, where " . . . the lowest number of vertebrae was produced at intermediate temperatures, the value rising both with higher and with lower temperatures."¹ The other explanation is that the Bay of Fundy ocean pout are actually genetically different. Under the circumstances, this seems to us the more logical hypothesis. Additional data are needed to confirm this finding, especially since only one sample from the Bay of Fundy has been examined. There is no evidence from the present data that the number of vertebrae in fish from the same locality varies with the year in which they were born as demonstrated by Schmidt (*loc. cit.*); this is probably because the time of spawning of the American ocean pout coincides with a fairly regular temperature—a temperature which may vary in the different localities over the range of this species, but which, in combination with other factors, may control (in part at least) the time of spawning (pp. 73-77). It would be of great interest to carry this study further by filling in the gaps with samples from Maine, New Hampshire, northern Massachusetts and New Jersey waters and by obtaining additional collections from locations already sampled. Our own suspicion is that there are two major genetically separate populations of ocean pout, one in the northern part of the range including at least the Bay of Fundy, and one in the more southern part of the range at least from northern Cape

¹ Just at the time this paper was going to press, an article by Å. Vedel Tåning reached this country (Experiments on meristic and other characters in fishes. 1. On the influence of temperature on some meristic characters in sea-trout and the fixation-period of these characters. Medd. Komm. Havundersøg., Fisk., 11 [3]: 1-66. 1944). This work confirms Schmidt's (*loc. cit.*) findings that the highest number of vertebrae occur in fish raised at high and low temperatures, and that the lowest values are obtained at intermediate temperatures. Tåning demonstrates further that the number of rays in the dorsal and pectoral fins increase with rising temperatures. In regard to the fixation-period of the number of vertebrae, he states that it is presumably " . . . situated about the days or perhaps the hours, when the cell groups of the mesoderm segments in the tip of the tail have been separated." Usually the number of myotomes specific to the species is developed prior to hatching; but there are exceptions, *e. g.*, several oceanic muraenoid fishes which add numerous myotomes after hatching.

Cod south. Within these two divisions there are minor sub-populations which probably vary in their degree of distinctness; for example, the Long Island Sound sub-population is apparently set off from neighboring groups so that there is no intermixture, while the Block Island and southern Cape Cod ocean pout probably intergrade to some degree. Just where the dividing line between these two major genetically separate populations might occur is questionable, but clearly it should be somewhere between northern Cape Cod and the Bay of Fundy. The importance of additional collections and further investigation, both as a contribution to the life history of the ocean pout and because of the general implications of the subject to theoretical biology, needs no emphasis.^{1, 2}

¹ After the present work had gone to press a paper by Vilh. Ege came to our attention (A transplantation experiment with *Zoarces viviparus* L. C. R. Lab. Carlsberg. *Physiol.* 23 [17]: 271-384. 1942). Ege's paper presents information on the relation between hereditary differences and differences produced by the environment. Characters investigated are the numbers of vertebrae, hard rays in the dorsal, and pectoral rays. The nature of the annual variations in vertebral number as reactions to the environment is illustrated by the parallel fluctuations of the values in the successive year-classes of two different populations over a period of years; it is also demonstrated by comparison of the embryos of the different year-classes with their mothers. The effects of genotypical influences are also demonstrated. The dorsal rays are not suitable for similar detailed analysis, but the results of pectoral fin-ray counts lead to the conclusion that the differences in value in this case are not hereditarily conditioned, but are exclusively of phenotypical nature.

² C. L. Hubbs, on reading this section on racial analysis in galley proof, suggested an alternate explanation of the material. He is inclined to interpret the data to indicate four races as follows: (1) An ocean race with about 140 vertebrae represented by samples A, B, C and D in Fig. 21 and Table XIA; sample A may represent a mixture of Massachusetts Bay and ocean fish. (2) An intermediate inshore race with about 138 vertebrae represented by samples E, F, G and H including the Martha's Vineyard and Block Island areas; the normal dispersion indicates that the samples are not mere mixtures of the two races on either side. (3) A Long Island Sound race with 136 vertebrae, comparable with fjord races of *Z. viviparus*. (4) A Bay of Fundy (Passamaquoddy Bay) race with 134-135 vertebrae, even more comparable with a fjord race. It seems clear that marine species in enclosed waters often have reduced numbers of vertebrae, although the factors involved (possibly higher temperatures, reduced salinities, or other physical and chemical or mere space factors) are unknown. If this interpretation is correct, the apparently parallel variation of the oviparous and viviparous species is most notable.

FEEDING HABITS¹

Comments on the feeding habits of the ocean pout were made as long ago as 1804 by Peck, who noted a preponderance of echinoderm material in the specimens he examined (p. 32). Storer (1839, 1855) listed 16 molluscan shells from their stomachs. Goode (1884) stated that the ocean pout "feeds upon crustaceans and mollusks . . .," and similar generalities are to be found throughout the literature. Clemens (1920) noted that the chief article of food in the Passamaquoddy Bay region is sea-urchins; other less abundant forms were barnacles, snails, small clams, hermit crabs, whelks, serpent stars and annulate worms. Clemens and Clemens (1921) recorded the identifiable stomach contents of 75 ocean pout in detail and came to the conclusion that this fish draws on molluscs (23 species), echinoderms (3 species), and Crustacea (12 species) almost exclusively for its food; they also listed three Annelida and a number of Chordata, including two small fish. The most common items of diet, in descending order, were: 1.) sea-urchin (*Strongylocentrotus dröbrachiensis*), 2.) whelk (*Buccinum undatum*), 3.) barnacle (*Balanus balanoides*), 4.) black mussel (*Mytilus edulis*) and tunicates, and 5.) mussels belonging to the genus *Modiolaria*. Bigelow and Welsh (1925) sum up the feeding habits as follows: "The American eelpout feeds on shelled mollusks, both bivalve and univalve, crustaceans large and small, echinoderms and other invertebrates, and less often on fish. . . . A large specimen caught in Massachusetts Bay, January, 1924, was packed full of brittle stars (ophiurans), spider crabs, and small sea scallops (*Pecten magellanicus*)."

Wiley and Huntsman's (1921) observations on feeding habits are quoted on page 35. The work of MacKay (1929a) on the digestive system of the ocean pout also deserves mention. After a brief account of the anatomy of the alimentary tract and its appendages, this author discussed gastric digestion. Although it was possible to extract a proteolytic enzyme from the gastric mucosa, there is good evidence that this enzyme does not play an important role in gastric digestion. The difficulty of extraction, indicating its paucity, and the insufficiently acid reaction of the stomach (pH 6.5-8.4 in both fasting and fed animals) for the activity of a pepsin-like enzyme, provide evidence that this proteolytic enzyme is unimportant. "These facts show that if

¹ In presenting this account, we wish to reaffirm (p. 6) our indebtedness and gratitude to Pfc. F. E. Smith.

peptic digestion takes place in the stomach of the eel-pout it plays a subordinate or secondary part. The protein substances in the food of this animal are digested chiefly by the trypsin of the pancreatic juice, which probably regurgitates into the stomach." In a second paper on the bile in different fishes, MacKay (1929b) notes that in contrast to the neutral or slightly alkaline condition in warm-blooded animals, the bile in a series of fishes investigated, although sometimes neutral, tended toward the acid side. Thus the pH of gall-bladder bile in the ocean pout ranged from 5.4-6.2.

By way of comparing our ocean pout with the European *Zoarces viviparus*, the detailed work of Blegvad (1917) on the food of fish in Danish waters is of particular interest. Blegvad states that the viviparous blenny is one of the most common fishes in the plant region of the Kattegat Sound, Belts and Baltic, and contrasts it with other species which seek their food almost exclusively among the small fish and crustacea of the weed vegetation as follows:

. . . *Zoarces*, on the other hand, although devouring a quantity of small crustaceans, which . . . make up almost half the entire stomach content, subsists to an essential degree upon the molluscs found in or on the bottom, or on the leaves of plants, such as *Macoma baltica*, *Cardium*, *Mytilus*, *Modiolaria discors*, *Rissoa* and *Hydrobia*, likewise various worms, especially *Pectinaria Koreni*, insect larvae, both the green ones living in the weed, and the red *Chironomide* larvae which live in the bottom. Finally, some few Ascidians (including *Ciona canina*), and a not inconsiderable amount of vegetable remains, but only a very slight quantity of small fish (abt. 1/35th of the weight of content of stomach). Among crustaceans, *Idothea* and *Gammaridae* are predominant, these two together making up about half the total content. The young of *Zoarces* eat not only copepods (*Harpacticoida*) but will immediately after birth (at which stage they have, however, already attained the comparatively large size of 4-5 cm.) attack *Diastylis*, ostracods, young *Gammaridae* and *Idothea*, and also young molluscs. *Zoarces* procures its food by a slow and methodical examination of every weed clump. The observer chancing to come upon one of these fish in search of prey among the *Zostera* will notice that it glides along with a very slow and easy undulating movement close to the bottom. Now and again it will take a great mouthful of weed, whence it might seem to be grazing, so to speak, on the vegetation, this constituting its food; as a matter of fact, however, one may soon discover that the fish, shortly after having taken such a mouthful, ejects the greater part of the vegetable mass, which it has only taken for the sake of the crustaceans and molluscs living thereon. As a rule, they do not succeed in separating the vegetable matter completely from the animal, especially the finest threads of algae; . . . no less than 106 gr. or 1/9th of the total stomach content examined consisted of algae, remains of *Zostera*, and plant detritus. A further

32 gr. consisted of detritus and sand, evidently swallowed involuntarily together with animals living buried in the bottom, such being found therewith in the stomach content. Zoarces masticates its food very thoroughly; on investigating a portion of the stomach contents by mixing it with clear water, the surface will be found covered with tiny fragments of the empty skeletal parts of small crustaceans; even the small *Rissoa* and *Hydrobia* are as a rule found crushed in the stomach contents. On examining Zoarces in the morning, before daylight, they will be found empty, or at any rate with very little in the stomach . . . It would thus seem that Zoarces do not feed at night, or if at all, less than during the day.

METHODS

As the various samples of ocean pout listed in Table V were "processed" through the laboratory (p. 67), the contents of the stomachs (as well as a variable but small amount of neighboring intestinal material) were removed and preserved together in 10 per cent formalin. Each jar was fully labelled with the corresponding laboratory serial numbers so as to enable reference to all other data for each collection. After a certain amount of experimentation several methods were adopted as standard practice in analyzing the stomach contents and obtaining the relative proportions of the different components.

Small samples. When the preserved sample was less than a half pint, or if it contained a single food item in heavy predominance, it was analyzed completely. Quite frequently the sample was divisible into two components—heavy (shells, tests, sand, *etc.*) and light (most Crustacea, worms, flesh of molluscs and echinoderms, mucous fixed by formalin, *etc.*). These two parts were separated by adding water, stirring and pouring off the top fraction before it settled. Two or three such fractionings produced virtually complete separation and resulted in washing the material sufficiently to facilitate analysis. Each fraction was then resolved as far as possible into its component groups without the aid of magnification in flat enamel pans under water. Shells and tests were for the most part sorted to species at this time; Crustacea were separated into Peracarida, Natantia and Reptantia (Pratt, 1935), and such unique forms as caprellids, Cumacea and most of the crabs were sorted out if recognized. By this process the heavy component was often fully resolved, whereas the lighter fraction never reached that condition. The recognition of the different and new divisions with the naked eye, as well as the identification of fragments, of course improved rapidly with experience. Unrecog-

nizable items were set aside for more detailed examination. Such material as remained after sorting was further searched under the binocular microscope, spoonfull at a time; all strange or new items were removed, and all sizable pieces of standard forms such as Crustacea or sand dollars were picked out. An estimation of the amount of the remaining material that was recognizable was then made; for instance, the quantity of echinoderm spines or the amount of crustacean legs and sclerites occasionally reached an appreciable percentage. In cases where one food was heavily predominant in the whole sample, a particular mollusc perhaps, the soft material that was obviously molluscan was assumed to be that of the particular species identified from the shell, and the percentage estimated. Finally a considerable proportion of the sample remained as an unidentifiable component—the digested and otherwise amorphous material including mucous from the fish.

The various groups resulting from the sorting described above were next examined in detail and identified as far as possible. After the sorting of the sample had been completed as far as was practical, the component parts were compared volumetrically. At first such hard, loose items as sand dollar tests, scallop shells, *etc.*, were measured by adding the drained material to a known amount of water and noting the increase in volume. But it was impractical to drain the fluid from the soft material in a comparable manner, so that the various components of this lighter fraction could only be measured directly in water by how high each came in a graduate after reasonable settling; thus the water included between the particles was also measured by this method. It was therefore decided that the same error should be included in the estimates of shells and tests if *comparable* measurements were to be obtained. In actual practice a graduate was rarely used. As a result of sorting the various items into vials it was possible to compare the relative amounts directly. A medium-sized item was chosen as equal to one, and other items were then compared with it and determined to be relatively $1\frac{1}{2}$, 3, $\frac{1}{6}$, *etc.* of the temporary standard, thus enabling the calculation of percentage values for each component. The percentage of unsortable material was further divided on the basis of the estimated percentages of recognized materials in it. In almost every sample a number of odd items were found that had inconsiderable percentage values. These were entered as "Miscellany," with the notation of any appreciable percentage, as judged by

comparison with the rest of the sample, or a notation of negligible quantity. The successive steps in the actual analysis of a typical sample (the collection of II-29-'44, 8 mi. S. of Block I., R. I.) illustrate the methods outlined above.

- No. 1. Sample divided by fractioning process into light and heavy portions.
- No. 2. Each portion searched and separated as far as possible with the naked eye. In this instance the heavy fraction was completely resolved with the following components: Unsortable soft material; Sand dollar tests; Amphipods; *Cancer irroratus*; 8-10 miscellaneous items, some such as *Pecten magellanicus*, caprellids, hydroids, etc., known and labelled, others unknown.
- No. 3. Microscopic examination followed. Several new items were discovered in the soft material, as well as pieces of forms already known to be present. The amphipods were sorted as far as possible, yielding *Unicola*, gammarids, a few more pieces of caprellids, and stray bits of a shrimp. Unknown items were identified as far as possible. The sample was now divided fully and stood in 18 different containers.
- No. 4. The relative volumes were next determined. The unsortable light material filled four vials; one of these was taken as a unit of one, yielding the following results:

Item	Relative Volume	Percentage
Light material	4	48.0
<i>Unicola</i>	$\frac{1}{8}$	1.5
<i>Cancer irroratus</i>	$\frac{1}{2}$	6.0
Nudibranchs (sp.)	$\frac{5}{8}$	8.0
Sand dollars	$2\frac{3}{4}$	33.0
Miscellany (13 items)	$\frac{1}{4}$	3.0

- No. 5. Analysis of the light material under the binocular microscope resulted in the following estimates:

Sand dollar (spines).....	10%
<i>Unicola</i>	17%
Gammaridae.....	3%
Unidentifiable material (mucous, digested sand-dollar flesh, etc.).....	70%

- No. 6. Combining Nos. 4 and 5 gave the total analysis of the sample as follows:

Unidentifiable material.....	33.5%
Gammaridae.....	1.5%
<i>Unicola</i>	10.0%
<i>Cancer irroratus</i>	6.0%
Nudibranchs.....	8.0%
<i>Echinarachnius parma</i>	38.0%
Miscellany.....	3.0%

1. Sand.....trace
2. Hydroid.....2 fragments
3. Parasitic Acanthocephala....1 specimen
4. Unidentifiable Annelida....1 fragment
5. Worm tubes (one containing
annelid).....2 specimens
6. *Phascolion strombi*.....1 specimen
7. Caprellidae.....8-10 pieces
8. *Crago septemspinosus*.....parts of 4 specimens
9. *Pagurus longicarpus*.....1 specimen
10. *Cardium pinnulatum*.....1 shell
11. *Pecten magellanicus*.....several pieces
12. *Ensis directus*.....1 small specimen
13. Eggs (crab?).....circa 50

Large samples. Many samples were so large that, unless they were composed almost entirely of one species, the time consumed in sorting would have been so great as to make impractical the analysis of the whole as described above. In such instances, two or three representative portions of the total sample were taken for sorting. Such portions were taken by first mixing the whole gently but thoroughly, and then spreading it out in a pan, surplus fluid first having been drained off. Two or three rectangular areas were next enclosed by microscope slides set into the material on edge so that they went clear to the bottom. The contained material was then entirely removed by spoon and pipette. By this method the relative proportions of heavy and light material were maintained—a necessary qualification since some settling was unavoidable. Each portion was then treated in the manner previously described for “Small samples,” each being resolved into its component parts and the percentages determined. The various portions from each sample agreed with one another reasonably well throughout, the percentage variation being relatively small. They were therefore assumed to be representative of the whole, and the percentages of the different portions were averaged to obtain final estimates.

In every case the whole sample was scanned for obvious discrepancies in the percentage values and for odd items. If a particular species that had not been present in the analyzed portions appeared in an appreciable percentage, its value was estimated and the other figures raised accordingly. Sometimes it was necessary before sampling to remove a few large items such as sea mice (*Aphrodita*), fair-sized spider crabs, large clams, *etc.* The percentages of these items

TABLE XII. ANALYSIS OF STOMACH CONTENTS FROM 21 SAMPLES OF OCEAN POUT FROM DIFFERENT AREAS. RANGES FROM 1-100. THE PERCENTAGE VALUES ARE IN TERMS OF VOLUME. PLUS SIGNS INDICATE PRESENCE OF THESE MINOR ITEMS SEE U

Locality	Bay of Fundy	Northern Cape Cod			Southern Cape Cod		Block Island Sound
Date	VI-15 to X-25, '43	I-20-'44	III-15-'44	V-30-'44	III-10 to 13-'44	V-30-'44	IV-7-'43
Number of stomachs preserved	73	90	71	86	49	93	15
UNIDENTIFIABLE MATERIAL	25.0%	28.0%	43.0%	29.0%	...	26.0%	14.0%
MISCELLANEOUS:							
Sand and/or stones	+	...	...	2.0%	...	1.0%	9.0%
Algae (several spp.)	+	...	...	...	...	...	...
Mud tubes	...	+	+	+	...	+	...
Membranous tubes	...	+	+	+	...	+	...
Sand tubes (small and brittle)	...	...	+	+	...	+	...
HYDROIDS	+	...	+	+	+	+	+
ACANTHOCEPHALA (PARASITES)	+	+	+	...	...	...	...
NEMATODA (PARASITES)	+	+	+	...	...	...	...
ANNELIDA:							
<i>Aphrodita hastata</i>	6.0%	+	4.5%	...	...	0.5%	...
<i>Lepidonotus squamatus</i>	+	...	...	...	...	...	...
Terebellidae?	...	...	+	+	...	...	...
<i>Cistenides</i> (tube)	...	...	...	...	...	...	...
<i>Spirorbis</i>	+	...	...	...	...	...	...
Sabellariidae?	...	+	...	...	...	...	...
Other annelids	1.0%	+	+	...	...	...	...
SIPUNCULIDA:							
<i>Phascolion strombi</i>	+	...	...	+	...	...	...
MYSIDACEA:							
<i>Heteromysis formosa</i>	...	...	...	...	...	...	...
CUMACEA:							
<i>Diastylis bispinosus?</i>	...	...	+	...	...	+	...
Other Cumacea	...	...	...	...	...	...	...
AMPHIPODA:							
Gammaridae	13.0%	...	9.0%	+	19.0%	25.0%	1.0%
<i>Ampelisca?</i>	...	...	+	...	...	...	...
<i>Unicola</i>	...	...	...	18.0%	...	+	4.0%
Caprellidae	+	5.0%	+	+	...	...	+
Other amphipods	...	+	...	...	...	...	...
ISOPODA:							
<i>Edotea triloba?</i>	...	...	...	+	...	...	...
<i>Cirolana concharum?</i>	...	...	...	...	...	+	...
STOMATOPODA:							
<i>Chloridella</i>	...	...	...	...	...	...	...
DECAPODA:							
<i>Crago septemspinosus</i>	...	...	+	...	...	...	...
Pandalidae	...	+	...	...	...	...	...
<i>Upogebia</i>	...	...	...	...	...	...	...
<i>Pagurus longicarpus</i>	...	...	6.0%	+	...	...	...
<i>Pagurus pollicaris</i>	...	...	1.0%	...	...	...	...
<i>Libinia</i>	...	...	4.5%	...	...	...	...
<i>Cancer irroratus</i>	...	...	2.0%	+	...	2.0%	9.0%
<i>Pinnixia?</i>	...	...	...	...	...	...	...
PYCNOGONIDA:							
<i>Tanystylum?</i>	+	...	...	...	...	...	...
Nymphonidae	+	...	...	...	...	...	...
GASTROPODA:							
Pteropoda	...	...	...	...	...	...	...
Nudibranchiata	...	...	...	...	...	...	...
<i>Retusa pertenuis</i>	...	...	+	+	...	...	...
<i>Acteocina canaliculata</i>	...	...	...	...	...	...	...
<i>Margarites groenlandicus</i>	+	...	...	...	...	...	...
<i>Margarites cinerea</i>	...	...	...	+	...	...	...

FOR DETAILED LOCALITY DATA SEE TABLE V. THE NUMBER OF STOMACHS IN THE DIFFERENT SAMPLES AT THE ITEM WAS LESS THAN 1 % OF THE WHOLE SAMPLE; FOR SUM TOTAL PERCENTAGES OF "MISCELLANY" (BOTTOM OF TABLE)

[illegible]

TABLE XII. ANALYSIS OF STOMACH CONTENTS FROM 21 SAMPLES OF OCEAN POUT FROM DIFFERENT AREAS. RANGES FROM 1-100. THE PERCENTAGE VALUES ARE IN TERMS OF VOLUME. PLUS SIGNS MEAN PRESENCE OF ITEM. THESE MINOR ITEMS SEE UNDER

Locality	Bay of Fundy	Northern Cape Cod			Southern Cape Cod		Block Island Sound Area	
Date	VI-15 to X-25, '43	I-20-'44	III-15-'44	V-30-'44	III-10 to 13-'44	V-30-'44	IV-7-'43	V-11-'43
Number of stomachs preserved	73	90	71	86	49	93	15	4
GASTROPODA—Cont.:								
<i>Odostomia seminuda</i>	+	...	...	...	...	+	...	...
<i>Polynices triseriata</i>	...	...	...	...	...	...	...	...
<i>Polynices heros</i>	...	...	+	+	...	...	...	...
<i>Polynices groenlandicus?</i>	...	...	+	+	...	...	...	...
<i>Velutina laevigata</i>	...	...	+	+	...	...	...	...
<i>Lamellaria</i>	...	...	+	+	...	...	...	...
<i>Urosalpinx</i>	2.5%	...	...	+	...	...	...	...
<i>Mitrella lunata</i>	...	...	...	+	...	...	...	...
<i>Anachis avara</i>	...	...	...	+	...	...	...	...
<i>Nassarius trivittatus</i>	+	...	+	+	...	+	...	...
<i>Colus pygmaeus</i>	+	...	+	+	...	+	...	...
<i>Lora nobilis</i>	+	...	+	+	...	...	...	...
<i>Lora harpularia?</i>	+	...	...	...	...	...	...	...
<i>Hydrobia minuta</i>	...	...	...	+	...	...	...	...
Unidentifiable	...	...	...	+	...	...	...	...
PELECYPODA								
<i>Nucula proxima</i>	...	...	...	...	...	+	...	...
<i>Nucula delphinodonta?</i>	+	+	...	...	...	...	...	...
<i>Nuculana tenuisulcata</i>	...	+	...	...	...	...	...	...
<i>Yoldia sapotilla</i>	+	+	...	...	...	+	...	...
<i>Yoldia limulata</i>	...	...	...	...	...	...	...	...
<i>Pecten islandicus</i>	10.0%	...	...	...	...	...	...	...
<i>Pecten magellanicus</i>	...	...	6.0%	29.0%	...	...	6.0%	...
<i>Mytilus edulis</i>	...	...	...	+	...	...	...	...
<i>Modiolus modiolus</i>	+	...	...	...	...	...	...	...
<i>Modiolus byssus</i>	+	...	...	...	...	...	...	...
<i>Modiolaria nigra</i>	+	...	...	+	...	+	...	...
<i>Crenella glandula</i>	...	...	+	...	...	...	...	...
<i>Astarte castanea</i>	...	...	...	+	...	...	...	+
<i>Astarte</i>	...	...	...	...	...	...	...	...
<i>Cardium pinnulatum</i>	1.7%	+	+	3.0%	...	+	...	...
<i>Mulinia lateralis</i>	...	...	...	...	...	...	...	...
<i>Venus?</i>	+	...	...	...	...	+	...	...
<i>Callocardia convexa</i>	...	...	+	...	...	...	...	...
<i>Ensis directus</i>	...	...	...	...	...	...	...	...
<i>Mya arenaria</i>	7.0%	...	...	...	...	...	...	...
<i>Saxicava</i>	+	...	...	+	...	...	...	...
<i>Cochliodesma leanum</i>	...	...	+	...	...	...	...	...
<i>Lyonsia hyalina</i>	...	...	...	+	...	+	...	...
<i>Pandora</i>	+	...	...	+	...	...	...	...
<i>Myrtaea</i>	...	...	...	...	...	...	...	...
ECHINODERMATA:								
<i>Solaster endeca</i>	+	...	...	...	...	...	...	...
<i>Asterias vulgaris?</i>	+	...	...	...	...	...	...	...
<i>Ophiura robusta</i>	...	67.0%	13.0%	...	...	...	...	...
<i>Ophiuræ</i>	1.0%	...	...	...	...	...	...	...
<i>Strongylocentrotus drobrachiensis</i>	18.0%	...	...	+	...	...	...	...
<i>Echinarachnius parma</i>	+	...	9.0%	16.0%	81.0%	44.0%	34.0%	18.0%
TUNICATA:								
<i>Molgula?</i>	1.3%	...	+	...	...	+	21.0%	+
VERTEBRATA:								
<i>Clupeidae</i>	7.0%	...	...	...	...	...	...	...
<i>Myoxocephalus octodecimspinosus</i> (eggs)	...	...	...	...	...	...	...	...
MISCELLANY								
	5.0%	+	2.0%	3.0%	+	1.5%	2.0%	3.0%

were determined by the relative volume process (No. 4, p. 122). Portions of the remaining sample were then analyzed, and the values of the different items calculated on a correspondingly lowered percentage basis.

In certain groups it was impossible to identify the items to species or even genus. Referring to the Gammaridae, this group in our listing probably includes several species and possibly other closely allied Amphipoda. Even if these were identifiable, any estimate of the relative quantities of each of the types involved would have been virtually impossible since too many of the individuals were fragmented.

Furthermore, the accuracy of the percentage figures derived for each item in the separate stomach content samples (Table XII) is not very high in certain respects. For instance, if food as such be considered, identical values of nudibranchs or amphipods on the one hand, and *Pecten* shells or sand dollar tests on the other, must differ considerably in food content. Even the volumes of the different animals before digestion would differ considerably, and not all the items would change volume in the same direction or degree. But in comparing the relative percentage of one item through a series of samples, the figures are probably fairly accurate. For example, if in one sample the value assigned to *Pecten* was 15 per cent, and in another it was 30 per cent, the second sample would have very close to twice as much *Pecten* as the first. The same item was always measured in the same way. Thus the percentages obtained for any particular item bear proper relation to each other throughout. It is for this reason that the percentage figures in Table XII read at times to the nearest 0.5 per cent and were not rounded to the nearest 5.0 per cent. The accuracy of the absolute values is approximately ± 5.0 per cent.

RESULTS OF ANALYSIS

The analysis of the stomach contents from 21 samples of ocean pout from different localities are shown in Table XII. Note that the stomach contents of over 850 ocean pout were examined in the course of this work, and that the identifiable forms include a wide variety of invertebrates as well as a number of chordates.

The most common item of diet is to be found in the Gammaridae, with the sand dollar (*Echinarachnius parma*), the crab (*Cancer irroratus*) and *Unicola* running close seconds. Among the molluscs, *Cardium pinnulatum* appears with surprising regularity, although in

minimal quantities, while members of the *Pecten* and *Yoldia* genera are occasionally eaten in large quantities. Tunicates also make up a portion of the stomach contents with considerable frequency. The eggs of the sculpin (*Myoxocephalus octodecimspinosus*) are sometimes taken in great quantity (Block Island Sound area, II-20-'44); these eggs are often laid in the dead man's finger sponge (*Chalina*) in the winter and afford a good source of food to those fish which are capable of exploiting it. We have found large masses of sculpin eggs in the cod (*Gadus morhua*), along with stray pieces of sponge which they also ingest, but no such pieces of sponge were found in the stomachs of ocean pout which had fed on these eggs—a probable indication that the mode of feeding described by Blegvad (1917) on page 119 for *Zoarces viviparus* holds true for its American counterpart. The eggs of the sea raven (*Hemitripterus americanus*), are also laid in association with this sponge (Warfel and Merriman, 1944); we have found these eggs in the stomachs of ocean pout which were not included in the detailed analyses in Table XII, as well as in the stomachs of cod.

Bigelow and Welsh (1925) indicate their belief that ocean pout not infrequently feed on other fish, but the results of the present study do not confirm this. Apart from demersal eggs, fish remains were found in only one of the 21 samples; these were in the collection from the Bay of Fundy and were probably herring which had sunk to the bottom after death. In short, it seems most unlikely that ocean pout feed on living fish to any appreciable extent; rather, it appears that this species is essentially a bottom feeder, and that the only fish it takes are those that have recently fallen to the bottom dead, or that live in the shelter of plants which the fish masticates for associated animal life, as indicated by Blegvad (1917). Conclusions as to the piscivorous habits of this species are dubious when based on its capture with fish-baited lines and on the evidence from Willey and Huntsman (1921), who fed fish to ocean pout in captivity; in view of the data here presented, these observations are more likely to indicate that this species is at times a scavenger, a fact which would appear to be wholly compatible with its catholic choice of bottom and near-bottom fauna.

In general, the number of empty stomachs in the samples listed in Table XII was small. With the exception of the small samples in the fall and early winter of 1943 (Table V) and the three hauls on May 30, 1944, the percentage of recorded empty stomachs varied from 0.7-7.0

per cent of the total number examined. In the May 30, 1944, collections the percentage of empty stomachs ranged from 10.5–18.7 per cent, and it is conceivable that the consistently higher proportion of empty stomachs in these samples is significant; this may be indicative of a change of feeding habits preliminary to movement to the rocky habitat for the summer and fall months (p. 110). Indeed, it may possibly be that movement to these rocky areas is governed by choice of food in the late spring and early summer. In the fall and early winter the percentage of empty stomachs varied from 38.4–75.0 per cent. This might be taken as an indication that there is a tendency to stop feeding in the period preceding and during spawning, but the small size of the samples precludes any possibility of a well substantiated generalization on this matter. Moreover, in the sample of 18 fish taken on November 25, 1943, which was well after the conclusion of spawning, eight (44.4%) had empty stomachs. This fact might also be taken as evidence that movement from the rocky habitat in December is governed by food conditions. But here again, the small size of the sample makes this hypothesis mere speculation. Furthermore, the wide variety of food which this species takes makes it seem unlikely that any particular item or combination of items of diet would control its movements. Finally, in explanation of Table XII note that the figures after the entry, "Number of stomachs preserved," refer only to the stomachs which contained food material—i. e., they do not include those which were empty.

The present data are inadequate to confirm Blegvad's (1917) conclusion regarding *Zoarces viviparus* that feeding, if it occurs at all at night, is less than during the day. All the samples comprising our material were taken in the daytime. However, one (January 2, 1944) was taken during the first hour and one-half of daylight, and the number of empty stomachs constituted only 1.6 per cent of the sample.

Finally, this analysis of the stomach contents is of interest because of its parasitological implications. Cross reference should be made to the succeeding section as well as to the paper by Nigrelli in this issue for further information on the subject. In regard to the parasites of the digestive tract, the presence of *Acanthocephala* and *Nematoda* in the stomach contents has been noted in Table XII. The *Acanthocephala* occurred with a fairly high degree of regularity in the collections from the different regions, except for the three samples from northern Cape Cod and the one from Long Island Sound. *Nematodes*, on the

other hand, while present in the Bay of Fundy collection¹ and in two out of three samples from northern Cape Cod, were absent in all other collections except one from the Block Island Sound area on January 19, 1944.

On the matter of the discovery of possible intermediate hosts or vectors for certain of the parasites of the ocean pout, the data presented in Table XII provide clear indication of the relative frequency with which different organisms are eaten by *Macrozoarces americanus*; they thus offer direct clues in any investigation directed toward this end. However, where intermediate hosts are concerned the degree of parasitization of the final host may depend on the *frequency* with which the organisms are eaten and not on their size; the percentages in Table XII are volumetric, so that a low value opposite an amphipod probably represents more individuals than a much higher value for certain molluscs. Furthermore, the dates of the collections on which the stomach content analyses are based are not strictly comparable. Thus the sample from the Bay of Fundy was taken in the summer months, while all other samples were from winter and spring months. We have already stressed the seasonal movements of ocean pout in southern New England waters (p. 110), and it may well be that the feeding habits are different in the summer and fall rocky environment from what they are in the winter and spring when the fish are on relatively smooth bottom. Therefore, the possibility of parasitization resulting from the ingestion of a particular intermediate host found in the summer and fall rocky habitat should not be excluded; our data are inadequate to establish whether or not the feeding habits are significantly different in the summer and fall from those in the winter and spring.

¹ Clemens and Clemens (1921) stated: "Of 44 specimens examined for intestinal parasites, 45 per cent contained nematodes and 35 per cent tapeworms." They made no mention of Acanthocephala, and we encountered no tapeworms (*Bothriomonus intermedius* Cooper). The nematodes were identified as *Kathleena* sp. (see Nigrelli) and *Echinorhynchus* sp.

INCIDENCE OF *PLISTOPHORA MACROZOARCIDIS*
NIGRELLI AND OTHER PARASITES¹

When this microsporidian parasite was first called to our attention by R. P. Hunter of the Connecticut State Board of Fisheries and Game, little or nothing was known about it. Consequently the following major objectives were recognized.

1) To provide data on the percentage of infections by *Plistophora macrozoarcidis* Nigrelli and other parasites in population samples from as many scattered localities at different times as possible, thereby determining whether or not seasonal and regional differences existed.

2) To obtain an approximate estimation of the efficiency of the candling method (by transmitted light) used in the commercial filleting houses.

3) To determine the percentage of infections detected by gross examination and candling.

4) To observe whether or not the infections are more prevalent in one part of the body of the fish as compared with another.

5) To detect, if possible, any relation of infection to size, sex, stomach contents, etc.

Although these infection studies are primarily concerned with *Plistophora macrozoarcidis* Nigrelli, we observed and noted as many other infections of the flesh as possible, but neither assistance nor time were adequate to make more than preliminary observations on some of these parasites. Nigrelli has identified and described some of this material; our considerations are confined mostly to macroscopical observations. He has also dealt with the parasites from the digestive tract (refer to his paper, as well as to our section on the stomach contents), and has given an account of the parasites described previously for *M. americanus* by other workers.

In a study of this nature, where large quantities of material were handled, most of the *Plistophora* and nematodes were quite easily determined by their distinctive characters, but some bodies in the flesh were encountered which could not be identified without histological study. Time for this was not available. Therefore any questionable material (probably less than 5%) was noted and preserved. Some *Plistophora* are unquestionably among this material, as well as

¹ We wish to acknowledge our particular appreciation to Grace E. Pickford for her generous assistance and counsel in this study.

Chloromyxum and other bodies. In the following accounts and discussion only positively identified infections are considered.

Plistophora macrozoarcidis Nigrelli is a parasite of very great abundance in ocean pout from southern New England and appears to a lesser degree in the region of northern Cape Cod and St. Andrews, New Brunswick, Canada (Tables XIII, XIV, XVIII, Fig. 22, 23, pp. 138, 167). Sandholzer, Nostrand and Young (1945) report it as far south as New Jersey. The incidence varies considerably in different areas and at different seasons of the year. Although large infections may be found very occasionally in the round fish by palpation,¹ most of them are detected in the skinned fillets. Some of the larger ones on the surface of the fillets are readily apparent and others more deeply imbedded in the flesh are palpable, but for the most part candling is necessary to detect most of the infections, particularly the smaller ones. Of course the light must be adequate and the flesh not too thick if all are to be located (p. 136). These microsporidian parasites, which are intramuscular and appear to have a distinct specificity for the ocean pout's muscle (p. 152), may be found either anterior or posterior to the anus, or both (Tables XV-XVII, p. 156), and are often more numerous and of a larger size anteriorly than posteriorly. *Plistophora* vary in size as well as shape, depending on their age and stage of development (pp. 144-151). In the same collection, fish may be found with only a minute individual trophozoite as small as 0.5 mm., while others may contain numerous large and well-established lesions of many centimeters in length and width.

The *minute* infections, which involve only a single muscle, are either whitish, cylindrical and quite flaccid (presumably an early stage of infection when no spores or only immature ones are present) or cream-colored, smoothly ovoid to fusiform and firmer (a later stage with more advanced spore development). In candling, the former appear whitish and transparent, while the latter appear darker and opaque in contrast to the flesh, as do the larger ones also. A fish may show only one of these minute individual trophozoites, or more, but occasionally the flesh of the entire host is peppered with countless

¹ In the Block Island area, where the incidence was very high, we examined 707 specimens externally by palpation. Only 11 fish were determined as infected by this method (about 1½ %). In each case the infection was close to the skin and sufficiently large to distend it.

numbers of either the light or dark forms, or both. The light form was much more abundant in our January collections than later in the season (p. 168). Two, three or more of these minute fusiform trophozoites in adjacent muscles form *small* lesions. *Moderate* lesions (1 to 2 cm.) and *large* (2 or more cm.) are either firm or soft, light or dark; some are darker in the center and light on the periphery, sometimes oozy and pus-like. Considering the varying three dimensional aspects of the infections, our estimates of size are subject to a large degree of error and therefore they must be considered as very approximate. Partly or completely encrusted infections were observed occasionally, suggesting a host reaction to the infection (p. 155).

Metacercarial Cysts. Time permitted no more than a survey of the incidence of these parasites (Table XIII, pp. 144-151). They were abundant in all our collections of 1944 from northern Cape Cod to Long Island Sound. They can be observed only by candling clean skinned fillets, and then sometimes only by careful scrutiny. They appeared in the flesh as small round dots (not ovoid or fusiform as in *Plistophora*) somewhat larger than the head of a common pin, some of which were light, others dark, presumably depending on their stage of development or location (p. 204); some hosts showed only a few while others contained large numbers of them. They were present in any or all parts of the flesh but were most easily observed by transmitted light in the tail region, from the skinned side, where the flesh is thin. Foreign substances may have been interpreted as metacercarial cysts in some cases, but for the most part the figures stated in the data give a fair indication of the incidence.

Chloromyxum clupeiidae Hahn was observed very occasionally in the muscles; we can give no data on its actual abundance, since the positive identification of this parasite requires microscopical examination. Those which were positively identified were somewhat whiter than *Plistophora*, softer and more smoothly ovoid, without the papillary features which are characteristic of *Plistophora*. Those that we have observed do not reach a size of much more than one cm. When ruptured they are very oozy and pus-like, more so than *Plistophora* (see p. 190).

Porrocaecum decipiens (?) Krabbe. These round worms were present in all collections from Canada to Long Island Sound (Table XIII, pp. 144-151). The infestation was much heavier than *Plistophora* in the St. Andrews collection of 1943 (p. 138), but on the other hand they were present to a much lesser degree in the more southerly parts of the range, where the protozoan parasite was predominant. They were not as easily detected as the microsporidians unless they were present in large quantities; this difficulty of detection probably arises from the fact that their color for the most part is closely akin to that of the flesh. These nematodes are most efficiently detected by candling the skinned fillets, but oftentimes they were observed only when slight clouded areas indicated their presence. Some were observed when the flesh was cut, but they were most often deeply imbedded, coiled, and encapsulated; groups of two or three of varying sizes were occasionally found together. In Canada the worms are unquestionably detrimental to the marketability of the ocean pout, as judged by our sample, but from northern Cape Cod to Long Island they are not as significant as *Plistophora*.

Yellow bodies of a fatty nature were observed in numerous specimens, but their nature and function are not known. These were seen in the muscle of the abdominal region next to the skin, none being seen posterior to the anus. Macroscopically they appeared yellowish to orange, small and ovoid to large and irregular in shape; under the binocular these masses showed great numbers of small oily globules which floated to the surface of the water when separated from the mass. They were observed in specimens with or without *Plistophora*; sometimes microsporidian parasites and these masses were in close proximity; nematodes were present in a few specimens possessing fatty bodies. The incidence of these bodies was relatively low in the Provincetown and Long Island areas, higher in the Block Island and southern Cape Cod regions (Table XIII, pp. 144-151, 155).

METHODS USED IN DETERMINING INFECTIONS

Candling Technique. This method of examining the flesh for infections by transmitted light was consistently maintained. As much of the flesh as possible was removed by cutting close to the pectoral girdle and then lengthwise along the vertebral column to the tail; each fillet was then skinned. The carcass and fillets were examined for

any infections which were large and obvious enough to be seen without candling (gross examination) and these were noted. The fillets of each specimen were kept separate so that specific data could be recorded for each individual. They were thoroughly washed, since foreign substances on the surface reduced the efficiency of detecting small infections. The possibility of overlooking parts of *entire* fillets was early recognized, and therefore each one was cut into smaller sections. Since the anterior sections were much thicker than those posterior, they were sliced to as near the thickness of the posterior pieces as possible, but considerable variation still persisted. However, we are quite certain that few infections, if any, were overlooked because of the thickness of the fillets.

The candling was performed against a 10-inch diameter drop shade at eye level, a 100-watt bulb being used as a light source. The drop shade protected the eyes against the direct glare of the light, but the fillet, which was held at the lower edge of the shade, received the full strength of the light so that even the smallest infections could be detected easily. Each piece was subjected to candling from both sides, since infections embedded in the flesh often may be seen from one side only. Furthermore, the number of observers was limited to two, with the final decision regarding all infections resting with one worker. Only fresh material was used; much of it had to be placed in a freezer for varying periods because of the fact that it took many days to handle a large collection. Material preserved in formalin or alcohol is unsatisfactory, inasmuch as the flesh becomes relatively opaque and the parasites, particularly the minute ones, cannot be seen easily. The heads and viscera of specimens were not examined for infections as carefully as the flesh. In view of the fact that the candling method was new and unfamiliar, a few large collections taken in early January 1944 were used for experimentation and practice, thus making it possible to obtain consistent and accurate data on the subsequent collections.

Cubing Methods. The collections of 1943 were examined for infections in a very incomplete manner. Each specimen was filleted on both sides, but the skin was left attached, and the flesh was then severed over its entire length by numerous horizontal cuts down to the skin, these cuts being parallel and close to each other. Sometimes longitudinal cuts were made also which gave the flesh the appearance

TABLE XIII. *Plistophora macrozoarcidis*, *Porrocaecum decipiens* (?), METACERCARIAL CYSTS, AND YELLOW BODIES
DETECTED IN THE MUSCLE OF OCEAN POUT

Locality	Northern Cape Cod				Southern Cape Cod				Block Island				Long Island Sound	
	III/15/44		V/30/44		III/10-13/44		V/30/44		III/12/44		V/30/44		IV/6/44	
Date	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Total number of specimens in sample	72	—	102	—	52	—	104	—	162	—	123	—	150	—
Specimens infected with:														
<i>Plistophora macrozoarcidis</i>	21	29.0	4	3.9	21	40.4	48	46.2	105	64.8	53	43.1	70	46.6
<i>Porrocaecum decipiens</i> (?)	11	15.3	15	14.7	5	9.6	5	4.8	3	1.8	8	6.5	10	6.7
Metacercarial cysts	69	96.0	81	79.0	38	73.0	54	52.0	150	93.0	88	72.0	143	95.0
Yellow bodies	1	1.4	3	2.9	23	44.3	22	21.2	30	18.5	57	46.4	5	3.3

of being cubed. Thus it was possible to observe both the infections on the cut surface as well as the larger ones within the flesh. However, by this method minute infections and probably some of the larger ones could not be detected. To add further to the inaccuracy, numerous persons worked on the examination of the fillets, the horizontal and longitudinal cuts were irregular, and the observations were generally inconsistent. Since no conclusions can be drawn from these data which are not obtainable from the collections of the following year, they are omitted except for the collections taken at St. Andrews, New Brunswick, Canada.

THE ST. ANDREWS' COLLECTION OF 1943

Of the 98 specimens¹ from St. Andrews which were examined by the *cubing technique*, only five were infected with *Plistophora* (about 5%); obviously all infections were large enough to be seen without the aid of transmitted light and were present in specimens over 40 cm. Four specimens had only one concentration of trophozoites per fish, each located anterior to the anus in the abdominal region; in the fifth specimen the infections were small and scattered in the flesh posterior to the anus. But this same collection was highly infected with nematodes; these were found in 58 specimens (about 60%), ranging from 35.5 to 70.5 cm., and in many instances the infestation per specimen was so heavy that the flesh had a porous appearance. Of all collections studied, this one contained the highest nematode infections by far.²

It is of interest to mention here that Clemens and Clemens (1921) observed the flesh of 41 specimens from this same area and reported no *Plistophora*, although they obtained an incidence of nematodes which was similar to that found in our collection (about 60%).³ How-

¹ Two additional small specimens of this collection were preserved *in toto* and not examined for infection. However, these fish were so small that it is very unlikely that they contained any *Plistophora*, since specimens of approximately the same size in other collections contained no obvious parasites.

² Four specimens, taken in this same region on June 15-16, 1943 (Table V), which ranged in size from 59 to 74 cm., were also examined for parasites by the cubing method. All of these fish were infected with nematodes, and two were infected with *Plistophora*, of which one specimen contained only one infection of moderate size, while the other had three large ones anteriorly and a smaller one posteriorly.

³ Clemens (1920) stated:

Similar worms have been found in the muscles of flounders and cod taken in the same region and possibly this parasitism may be only local and only occur to any

ever, the largest number of nematodes which they noted in any one specimen was three, whereas in many of our specimens there were countless numbers. Unfortunately these authors did not state by what method they examined their specimens for parasites, but judging from the fact that they found no *Plistophora*, and only three worms at most in a fish, it is very probable that their examination was even more incomplete than ours. It is possible also that none of their specimens contained *Plistophora*, for their total sample of 41 specimens was less than half the number in our collection, and we obtained only a five per cent incidence in 98 specimens, which is relatively low. But there is also the possibility that their sample, as well as ours, may have had minute *Plistophora* in the muscle which were too small to be observed by the methods employed.

If Clemens and Clemens were accurate in their observations, and if no *Plistophora* were present in their sample, then it is suggested that the incidence of this microsporidian may be more abundant in some years than in others, it may have infested the ocean pout of the Bay of Fundy in recent years only,¹ the incidence may vary within the local populations of the Bay, or it may vary seasonally. Unknown factors, such as the feeding habits, may also be related to the incidence. Although no vectors are known for microsporidians, they may conceivably exist. The stomach contents of our specimens, when compared with Clemens and Clemens observations, suggest that the Gammaridae, *Aphrodita hastata* and *Urosalpinx* (Table XII) might serve as secondary hosts.

COMMERCIAL CANDLING

At both New Bedford and Provincetown, Massachusetts, observations were made at commercial filleting plants which showed that commercial candling is inadequate and that infected fillets were being shipped to market in spite of the apparent precautions.

A sample of 61 specimens (122 fillets) was observed at a processing plant at New Bedford on January 19, these fish having been taken

extent in certain years. Authorities on fish parasites are agreed that there is no evidence that these round worms can live in the human body and when the fish is cooked there is absolutely no danger. The worms do not render the fish unfit for food and if flounders and cod so parasitized find ready sale, the muttonfish need not be condemned.

¹ Sandholzer, *et al.* (1945), also suggested the possibility "that *Ichthyosporidium* [*Plistophora macrozoarcidis*] may be a recent parasite of this fish."

about six miles due south of Block Island. The specimens were fresh, and the viscera showed no signs of deterioration. The skinner, when culling, discovered sizeable infections in 15 of the fillets, all of which were discarded. The 107 fillets which remained were candled at the plant in the general routine manner on a rectangular box with frosted glass such as that used for candling *Sebastes marinus* (p. 141); two more fillets were found to contain infections. The remaining 105, which presumably would have gone to market, were then candled more thoroughly at our laboratory, and a large number of additional infections were observed as follows:—10 minute trophozoites; 13 small to moderate *Plistophora*; 12 questionable infections; and 1 nematode. Metacercarial cysts were also present in the flesh.

At Provincetown 61 specimens were observed at a processing plant the following day, these specimens having been taken about 10 miles SW. from Wood End Light in Massachusetts Bay on January 19, 1944, at a depth of about six fathoms on rocky, sandy bottom. The fish were in excellent condition and somewhat larger generally than those at New Bedford, the size range being 44 to 87 cm. Only one sizeable infection was detected by the cutter in the 122 fillets, and two more were found in the skinning process. The remaining fillets, which would have been marketed, were then taken to New Haven and placed in a commercial freezer for six days at a temperature somewhere between 0° and 10° F. These 119 fillets contained only minute trophozoites, the total number of which could not be ascertained, since two fillets had them scattered in great numbers throughout the flesh. A number of nematodes, five questionable infections and numerous metacercarial cysts were also observed.

Considering the inefficiency of the candling procedure at the New Bedford plant, it is not surprising that a large number of infections should pass unobserved, although none of them were of a large size. A limited amount of help for the number of fillets to be examined was obvious, and consequently fillets were usually passed over the candling box rapidly and mechanically without careful observation, or in such large bunches that infections might well pass unseen. However, it must be pointed out that these were the only observations made at a plant where candling was performed, and it may be highly unjust to base an appraisal on this one instance, since the results of further observations might give a much more favorable picture. At the Provincetown processing plant the fillets were not subjected to can-

dling, presumably on the basis that the ocean pout in the northern Cape Cod region are much "cleaner" than those from southern Cape Cod and Block Island, which is true.

Therefore it is concluded from the above observations that fillets infected with *Plistophora* were being shipped to market from both New Bedford and Provincetown, with those from the New Bedford area containing larger infections than those from Provincetown.

Fischthal (1944) observed 100 ocean pout fillets from Cape Cod Bay to determine the relative effectiveness of various methods of candling by the use of the same candling apparatus as that employed in detecting parasitic copepods or lesions in the rosefish, *Sebastes marinus*. This consisted of a rectangular wooden frame with a lightly frosted plate glass resting on it, and two or more electric light bulbs beneath the glass; he made no mention of the wattage used. It is obvious from his data that rapid candling, as performed commercially on ocean pout, detects only the larger concentrations and therefore only a part of the infected fillets or specimens, thus substantiating our observations at New Bedford and Provincetown. He obtained the following results by both rapid and detailed candling of the same lot of 100 fillets. By rapid candling both sides of the fillets with the skin removed he obtained a 21 per cent incidence, which included all the larger concentrations of trophozoites and some scattered individuals. By detailed candling of these same fillets he obtained a 34 per cent incidence, or an added 13 per cent due solely to additional individual trophozoites which had apparently passed unobserved in rapid candling.

Sandholzer, *et al.* (1945), used a candling box 18 x 6 x 6 inches with four 50-watt bulbs, a reflector and frosted glass. These workers examined a number of fillets on both sides to detect the lesions and concluded that, "In this investigation there was little difficulty in detecting lesions 10 mm. and over in diameter, although it was necessary to examine the fillets very closely on both sides in the case of the smaller lesions." Our own work confirms the need for careful observations to detect lesions of all sizes, for we found that some of the larger infections, well imbedded in the thick flesh of the abdominal region, were not discernible until the flesh was subjected to the light. By recandling commercially candled fish Sandholzer, *et al.*, found that about 60 per cent of the parasitized fillets had been overlooked, which is a much higher percentage than that obtained by our observations.

However, with the wide fluctuation in incidence in different areas, together with the fact that commercial candling was probably less thorough in 1943 than in 1944, a wide range of variation is highly probable.

FROZEN FISH, FILLETS AND INFECTIONS

The problem of obtaining some indication of the validity of a rumor which reported that *Plistophora* infections increase in size during storage was given only cursory consideration by us in view of the fact that the U. S. Fish and Wildlife Service was reported to be engaged in studies on this subject. Although our own work was by no means exhaustive or conclusive, certain features are of interest and appear to refute the conclusions reached by Sandholzer, *et al.*

These workers carried out experiments to determine if "individual lesions continued to increase in size and undergo degeneration in fillets under the usual conditions of storage," to determine if "non-infected flesh could become parasitized from contact with contaminated cutting tables, knives, or other objects," and whether or not "such fillets would develop lesions during storage." "The conditions of storage were comparable to those used in commercial cold storage." According to them,

The results obtained in the experiments that were conducted to determine the increases in areas of lesions in fillets clearly show that even with careful candling and proper storage, lesions will continue to develop. The data also indicate that flesh which appeared to be normal upon candling may develop lesions during storage.

In their discussion they stated further:

From a strictly practical viewpoint it is almost impossible to eliminate the parasite from fillets, at present. Should the high incidence of infection continue, normal fillets are certain to become contaminated during processing, and storage will permit the organism to develop. It is true, of course, that in none of the experiments was the fish subjected to quick freezing, nor were they held at extremely low temperatures. It may be that a commercial quick-freezing type of treatment might have held the parasite in check or killed it. However, the conditions held during the course of the experiments were probably superior to those employed in plants that do not produce frozen fish, and the results reflect what may be expected in ordinary commercial practice.

For our own observations we obtained 90 specimens (size range 46 to 91 cm.) from Provincetown which were placed in the freezer in the

round on January 21. These were from the same lot as the 119 fillets from 61 fish which had been observed at the processing plant in Provincetown and which had been taken 10 miles SW. of Wood End Light on January 19 (p. 140). Both the fillets and the round fish were placed in the freezer at the same time, and the latter were removed for examination on February 1, 3 and 7. When placed in the freezing plant the fish were in excellent condition and when removed from cold storage they were frozen solid and had to be thawed for many hours. No thermographic record was kept of the temperature at the freezer, but according to the officials at the freezing plant the temperatures vary from 0° to 8° F., with the temperature usually about 5° or lower in the winter. These conditions are similar to those of other freezing plants.

A thorough examination of these 90 fish by candling showed that infections were present in 46 (51%) but we found only one large infection in a male 75 cm. long. Of the remaining 45 specimens infected with *Plistophora*, 30 contained only one minute trophozoite, five had a few scattered minute or small ones, and 10 contained numerous minute or small concentrations of trophozoites, some of which had the parasites distributed throughout the flesh.¹ On the other hand, the 119 fillets which were candled after six days in the freezer contained minute trophozoites only, the three fillets with large infections having been discarded at Provincetown when they were found to be infected. Note that only *one large infection* was present in 90 fish (180 fillets) after 11 to 17 days in the freezer, and *no sizeable infection* appeared in the 119 fillets after six days in the freezer. When we consider the abundance of minute infections from which larger infections might have developed, it seems highly unlikely that infections increase in size during cold storage; it seems equally improbable that

¹ Except for the one large concentration, all of the infections were detected by candling. Obviously many of these fish had parasites located both anterior and posterior to the anus, particularly in those which had large quantities scattered throughout the flesh; in many instances the trophozoites were of both the light and dark form. Fifteen of the 33 females were infected, as compared to 31 of the 57 males, the incidence being higher in the males by only about eight per cent. The flesh of 18 specimens (about 20%) contained at least one or more nematodes: 11 had 1, 6 had 2 and 1 had 7 worms; this percentage was much lower than that obtained for the collection from St. Andrews, but it was the highest nematode count obtained in any of the collections from northern Cape Cod to Long Island Sound. Sixty-four of the 90 specimens (about 71%) appeared to be infested with metacercarial cysts.

lesions spread from an infected fillet to an uninfected piece of tissue if infections *in situ* do not spread. On the other hand, judging from our own data on the incidence as well as that of Fischthal (1944) and Sandholzer, *et al.* (1945), who observed minute trophozoites in the Cape Cod specimens, it is hardly conceivable that all the minute and small infections developed from sporoplasms while frozen.

DATA ON THE INCIDENCE OF PLISTOPHORA AND OTHER PARASITES

The following accounts of the parasites in seven collections taken in March, April and May 1944 form the basis upon which most of the discussion and conclusions are based. The procedure in handling these collections was identical in all instances, and therefore it is possible to make a direct comparison of one sample with another. Candling was performed throughout as outlined previously (p. 135). The data are recorded and listed by geographical areas for direct comparison with both the tables and figures.

NORTHERN CAPE COD

A.

Date: March 15, 1944.

Location: about 8 miles NNW. of Racepoint Light (Table V).

Number of specimens: 72.

Size-range of specimens: 45 to 98 cm. in total length.

Number of fish infected with *Plistophora*: 21 (about 29%), ranging in size from 52.5 to 76 cm. in length.

Number of males: 36; infected: 11.

Number of females: 36; infected: 10.

Specimens infected with nematodes: 11 (15.3%).

Specimens containing metacercarial cysts: 69 (96%).

All infections were either minute individual trophozoites or small concentrations; none large or moderate. Trophozoites of both the light and dark form varied in abundance from a single individual per host to countless numbers scattered throughout the flesh in two specimens. Only two ocean pout had small lesions, the highest number being three in one fish. A single infection was found in 12 specimens, multiple infections in 9. In all cases the infections were observed by candling. One female of 75.5 cm. showed yellow bodies, but there were no *Plistophora* in this specimen.

B.

Date: May 30, 1944.

Location: about 2 miles E. of Peaked Hill Buoy (Table V).

Number of specimens: 102.

Size-range of specimens: 25.5 to 94 cm. in total length.

Number of fish infected with *Plistophora*: 4 (about 4%), in specimens 51.5, 80.5, 93.5 and 94 cm. long.

Number of males: 60; infected: 4.

Number of females: 42; infected: 0.

Specimens infected with nematodes: 15 (14.7%).

Specimens containing metacercarial cysts: 81 (81%).

No large lesions; two moderate infections, one in the second specimen and one in the fourth; a single trophozoite in the first and a small concentration in the third. No light trophozoites. All infections detected by candling. Three females, 68 to 76 cm., contained yellow bodies, but no *Plistophora*.

Summary. Data from these two samples, as well as those of January 19 (p. 143), showed wide variation in the infestation by *Plistophora*. In January it was 51 per cent, in mid-March 29 per cent and at the end of May only 4 per cent, decreases of 22 and 25 per cent for the relative periods. Most of the hosts had only single trophozoites or small concentrations, with only one large infection in the January collection and two moderate ones in that of May. However, note that these collections were not obtained at the same locality, and that the samples varied with 90, 72, and 102 specimens, the May collection having a wider size-range than the other two.

Also, the light trophozoites were very abundant in January, noticeably less in March and entirely absent in the May collection; in January, 42 specimens (about 47%) showed these white forms, in March, 10 (about 14%). No *Plistophora* were observed in specimens below 51 cm., but larger samplings from below 51 cm. would probably reveal at least a few infections. There appeared to be no significant difference in the incidence by sex.

SOUTHERN CAPE COD¹

C.

Date: March 10-13, 1944.

Location: S. end of Nantucket Shoals (Table V).

Number of specimens: 52.

Size-range of specimens: 53.5 to 90 cm. in total length.

Number of fish infected with *Plistophora*: 21 (about 40%), all these over 59.5 cm.

Number of males: 27; infected: 11.

Number of females: 25; infected: 10.

Specimens infected with nematodes: 5 (9.6%).

Specimens containing metacercarial cysts: 38 (73%).

Smallest lot examined, with infections of all sizes in large numbers present. Six ocean pout had large concentrations, four of which showed additional moderate and small infections. Five fish harbored one or more moderate *Plistophora* and additional small or minute infections. The remaining infected ones had anywhere from one to many single trophozoites or small concentrations. A single infection was present in seven specimens and multiple in 14. No light trophozoites. Below 70 cm. a relatively greater number of fish were uninfected; above 70 cm. the inverse obtained, with infections more abundant in both size and number.

¹ Fischthal (1944) observed 4,152 fillets from Cape Cod Bay and southern New England, as well as a small collection from Casco Bay, Maine, from March 28 to August 18, 1943, and some infections were found in all collections regardless of where the fish were caught.

Since his percentages are based on the number of *fillets* infected, and ours on the *specimens* infected, a direct comparison is impossible. However, from the area below Cape Cod, extending from Block Island to No Man's Land, he examined 2,032 fillets (representing 1,016 fish), of which 138 (6.8%) were infected, with a variation of 3.9 to 10.5 per cent in the three samples. Of the 2,074 fillets (representing 1,037 fish) which he examined from Cape Cod Bay, 142 (6.8%) were infected, the percentage in the six samples varying from 1.0 to 34.0 per cent.

Even if one takes into consideration the fact that he based his estimates on the number of fillets rather than on the number of fish, his percentages still appear very low by comparison with our figures, particularly in the southern New England area (Table XIV). This worker does not state by what method these particular fillets were examined, but it is presumed from his figures that they were done by rapid candling comparable to the methods used in the commercial filleting houses. The figures he obtained in the Cape Cod area are more nearly comparable to ours.

By gross examination (*i. e.*, the rough examination when the fillets were cut and skinned) a total of 16 small to large lesions were found, by candling an additional 38, not counting the minute trophozoites; all infections were detected by gross examination in four fish, those in the other 17 by gross examination or candling. Five specimens were infected only anterior to the anus, one posterior, four both anterior and posterior, and in 11 the locations of the infections were mostly questionable. Twenty-seven infections were positively located, 21 being anterior to the anus, the other 6 posterior, all of varying sizes, omitting individual trophozoites. Yellow bodies were found in 13 females and 10 males, 53.5 to 88.5 cm. in length; 12 had *Plistophora*, 11 none.

D.

Date: May 30, 1944.

Location: about 8 miles SW. of the entrance to Muskeget Channel (Table V).

Number of specimens: 104.

Size-range of specimens: 48 to 72.5 cm. in total length, except for one specimen 87.5 cm.

Number of fish infected with *Plistophora*: 48 (about 46%), specimens from 53 cm. upward.

Number of males: 26; infected: 7.

Number of females: 78; infected: 43.

Specimens infected with nematodes: 5 (4.8%).

Specimens containing metacercarial cysts: 54 (52%).

This was a larger sample than the one for March, but the range was somewhat narrower and the fish were generally of a smaller size. Infections were present in all sizes and in large numbers, one specimen having as many as four large and two moderate concentrations; four fish had one or two large concentrations and additional moderate or small infections; fourteen had one or more moderate lesions, about half of which had additional smaller infections; the remaining infected individuals showed *Plistophora* varying from one individual trophozoite up to numerous small infections. A single infection was present in 25 fish, multiple in 23. Only one light trophozoite seen. Below 60 cm. the uninfected fish outnumbered the infected, but above that the latter were more numerous, as well as more abundant and larger.

By gross examination 23 infections were observed, and by candling

39, individual trophozoites not included. All infections in 10 fish were detected by gross examination only, and in the remaining 38 by gross examination or candling. Thirty-three small to large infections were anterior, 15 posterior. Nine fish were parasitized only in the abdominal region, nine posterior, five both anterior and posterior, and in the remaining 25 the parasites were mostly of undetermined position. Yellow bodies were found in 21 females and one male, 17 of which showed *Plistophora* and five none.

Summary. These two collections showed not only a high incidence in both samples, but it was actually higher in May than in March by about six per cent; the infections were very abundant and large in many specimens. The March collection consisted of only 52 specimens; that of May, 104; there was considerable difference in the size-range of the two collections. Both samples were obtained from fillet houses where grading and selection may have been employed, and therefore these two collections are not representative of the catch. Only one light trophozoite was present in the May sample. Both collections showed higher infection percentages in the abdominal region. A correlation of incidence to sex showed no difference in the March collection; in the May sample there was a much higher incidence in the females, which may be due in part to the uneven sampling of males (26) and females (78).

BLOCK ISLAND AREA.

E.

Date: March 12, 1944.

Location: about 5 miles due SW. of Block Island off the "SW Ledge."

Number of specimens: 162.¹

Size-range of specimens: 45 to 78 cm. in total length.

Number of fish infected with *Plistophora*: 105 (about 64%), from 49 to 78 cm. in length.

Number of males: 76; infected: 49.

Number of females: 87; infected: 55.

Specimens infected with nematodes: 3 (1.8%).

Specimens containing metacercarial cysts: 150 (93%).

¹ The two fillets of a 54-cm. specimen were accidentally destroyed and therefore are not included in the tabulations.

Largest collection studied, and the most heavily infected of all samples, with large and moderate lesions extremely numerous, not to mention smaller infections. Infections were abundantly represented in all size categories. They were generally more numerous and larger above 52 cm., but too few specimens below this length were studied to make this point conclusive. Many specimens were so completely infected that it was difficult at times to determine where one infection began and the other ended. The most heavily parasitized specimen had 15 large and four moderate concentrations, this individual being a male 65.5 cm. long. Twenty-six had anywhere from one to as many as 12 large *Plistophora*, with some fish having additional moderate, small and minute infections; 25 specimens had from one to three moderate concentrations with small and minute infections; the other infected specimens contained only small or minute *Plistophora*, these being present in numerous combinations and quantities. A single infection was found in 32 specimens, multiple infections in 73. Only seven contained one light trophozoite each.

A total of 130 infections were positively located as anterior and posterior to the anus, mostly of large and moderate sizes; 79 anterior to anus, 51 posterior, the individual trophozoites not included. Eleven specimens had infections only anterior, 4 posterior, 21 both anterior and posterior, and 69 specimens had infections whose locations were undetermined. The total number of large, moderate and small lesions was 220, 107 being detected by gross examination and 113 by candling, minute trophozoites not included. All lesions in 21 fish were detected by gross examination only, in 84 specimens by gross examination or candling. Yellow bodies were found in 25 females and 5 males, from 50 to 69 cm.; 19 contained *Plistophora*, 11 none.

F.

Date: May 30, 1944.

Location: 3 to 4 miles ENE. of Block Island.

Number of specimens: 123.¹

Size-range of specimens: 39 to 74 cm. in total length.

Number of fish infected with *Plistophora*: 53 (about 43%), ranging in size from 44.5 to 71.5 cm.

Number of males: 49; infected: 19.

¹ One female with a stub tail was not included in the tabulations for Table XVIII, Fig. 23.

Number of females: 74; infected: 34.

Specimens infected with nematodes: 8 (6.5%).

Specimens containing metacercarial cysts: 88 (72%).

A smaller sample than that of March, with the range in size slightly lower. These fish also were heavily parasitized. Above 60 cm. infections of all sizes were more abundant and larger, and were present in all size categories. Below 60 cm. the uninfected specimens were dominant. The most heavily infected individual was a female 69 cm. long with nine large concentrations. Thirteen additional specimens had one to three large infections per fish with additional moderate or small concentrations; in one case as many as six moderate and five small *Plistophora* were present in addition to a large one. Twelve specimens contained from one to three moderate infections, with a few additional small infections and individual trophozoites. The remaining parasitized specimens contained only small or individual infections. A single infection was found in 26 specimens, multiple infections in the same number. No light trophozoites were observed.

Twenty-three specimens had infections anterior, 13 posterior, 12 anterior and posterior, and 5 had them indeterminate in position. At least 107 large, moderate and small concentrations were definitely located, 69 being anterior to the anus and 38 posterior. The anterior *Plistophora* were more numerous and larger. A total of 110 large, moderate and small lesions were detected; 49 of these were discovered before candling, 61 after. All concentrations in 12 specimens were detected by gross examination, in 41 by gross examination or candling. Yellow bodies were present in 41 females and 16 males, from 45 to 71 cm.; 29 specimens with *Plistophora*, 28 without.

Summary. The March collection was more heavily infected than that of May and was the most heavily parasitized of any that was examined; this was the only one in which the infection was above 50 per cent. The incidence was lower in the May sample by about 21 per cent. Only a few light trophozoites were seen in the March collection, none in the May sample. These two collections also showed a high incidence anterior to the anus. The correlation of infections to sex showed no appreciable difference in males or females.

LONG ISLAND SOUND.

G.

Date: April 6, 1944.

Location: $3\frac{1}{2}$ miles N. of Pt. Herod, in Long Island Sound.

Number of specimens: 150.¹

Size-range of specimens: 33 to 62 cm. in total length.

Number of fish infected with *Plistophora*: 70 (47%), 37 to 62 cm. in length.

Number of males: 88; infected: 42.

Number of females: 61; infected: 27.

Specimens infected with nematodes: 10 (6.7%).

Specimens containing metacercarial cysts: 143 (95%).

Next to the largest sample studied, but with relatively few infections per specimen; no heavy preponderance of parasites in the upper reaches of the size-range, either in quantity or size. Up to about 47 cm. there were more uninfected than infected fish, but above this the infected specimens were more numerous except between 52 and 57 cm. Only four fish contained a single large concentration. Twelve other specimens had moderate infections, with additional small or minute *Plistophora*. The remaining infected specimens contained single minute trophozoites or small lesions. A single infection was found in 36 specimens, multiple infections in 34. The light trophozoites appeared singly in only two specimens.

Twenty-eight fish were infected anterior, 5 posterior, 6 both anterior and posterior, and 31 had *Plistophora* in questionable locations. A total of 55 infections were situated anterior to the anus and 12 posterior, not including minute trophozoites. Eleven small to large infections were detected by gross examination, 94 by candling. All the infections in eight were found by gross examination only, and in 62 specimens by gross examination or candling. Yellow bodies were seen in one female and four males, from 40.5 to 52.5 cm. in length; three had *Plistophora*, while two had none.

DISCUSSION

Marketing ocean pout. From observations made in January 1944 it was pointed out that thorough candling is essential in all areas if a clean product is to be marketed (p. 139), and the data obtained in the

¹ One specimen with sex undetermined omitted from Fig. 22 (series 3).

spring of the same year confirm this point. An examination of samples from Canada to Long Island Sound showed that the protozoan parasite appeared in at least some specimens from all localities. However, relatively few fish from the Provincetown samples showed larger lesions, whereas in the southern New England collections many fish contained one or more large concentrations. Furthermore, a much greater percentage of the infections were detected by candling than by gross examination (Table XIV, Fig. 22). In the March and May samples from Provincetown all parasites were detected by candling. In southern New England 5.3 to 13.0 per cent of the total samples contained specimens with infections which were detected by gross examination only, while 32.7 to 51.8 per cent showed *Plistophora* which were detected partly or entirely by candling.

Recently Sandholzer, *et al.*, in some controlled feeding tests on newly weaned kittens and pigs, stated, "The results of the feeding tests employing cats and pigs *indicate* [*italics ours*] that there is very little, if any, danger to their health in eating oceanpout parasitized with *Ichthyosporidium* [*Plistophora macrozoarcidis* Nigrelli]." Kudo (1924) reported that Microsporidia have been found only in invertebrates, fishes, amphibians and reptiles, and so far as known no microsporidian has been found which infects human beings. Furthermore, it is very unlikely that *Plistophora* is injurious to man, since thousands of ocean pout have been consumed in recent years by the public, and for many decades by fishermen without any apparent harm.

In view of these facts it seems reasonable to assume that the flesh can be eaten without much danger. But in order to market a clean product it is highly essential that only *skinned fillets* be sold and that candling be performed carefully and thoroughly in all areas, particularly in southern New England.¹

The parasite and its relation to the host body. From our own observations it appears that *Plistophora* has a distinct specificity for only the muscle of the ocean pout. In no instance has it been seen in the skin or body cavity wall, although numerous concentrations were im-

¹ However, before a final decision is arrived at regarding the market status of the ocean pout the metacercariae should be taken into account. These parasites are present in other regularly marketed marine products which are eaten in large quantities by the public, but presumably cooking destroys them and eliminates danger of infection in humans.

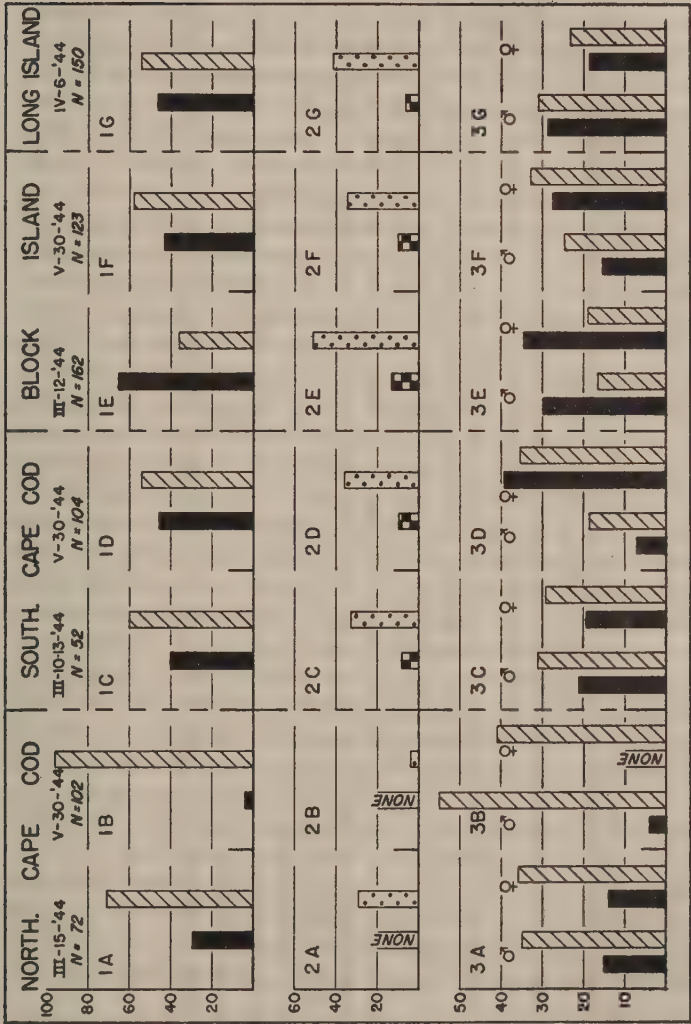


Figure 22. Series 1. ocean pout infected (black) and uninfected (shaded) by *Piistophora macrozoarcidis*; series 2. the infections detected by gross examination only (checkboard) and by both gross examination and candler (polka dots); series 3. the infected (black) and uninfected (shaded) by sex (one specimen omitted from E and G, footnotes, pp. 148, 151). All tabulations are expressed in per cent of total samples.

TABLE XIV. DATA SHOWING TOTAL NUMBER OF INFECTED AND NON-INFECTED OCEAN POUT BY AREA AND DATE; ALSO SPECIMENS WITH INFECTIONS DETECTED ONLY BY GROSS EXAMINATION AND BY CANDLING. ONE SPECIMEN OMITTED FROM COLLECTION OF MARCH 12. SEE FIG. 22.

Locality	Northern Cape Cod				Southern Cape Cod				Block Island				Long Island Sound	
	III/15/44		V/30/44		III/10-13/44		V/30/44		III/12/44		V/30/44		IV/6/44	
Date	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Number of Specimens.....	72	—	102	—	52	—	104	—	162	—	123	—	150	—
Specimens uninfected with microsporidia...	51	71.0	98	96.1	31	59.6	56	53.8	57	35.2	70	56.9	80	53.4
Specimens infected with microsporidia....	21	29.0	4	3.9	21	40.4	48	46.2	105	64.8	53	43.1	70	46.6
Specimens with all infections detected only by gross examination.....	0	—	0	—	4	7.7	10	9.6	21	13.0	12	9.8	8	5.3
Specimens with infections detected by gross examination or candling.....	21	29.0	4	3.9	17	32.7	38	36.6	84	51.8	41	33.3	62	41.3

mediately adjacent to these tissues. Furthermore, no positively identified *Plistophora* were seen in the viscera or heart, nor in any of the ocean pout's associates which have been studied in this laboratory.¹

Also, it is indicated that there may be mono- or multi-infection, as well as auto-infection, and that multi-infection may occur simultaneously or at different times. Judging by those fish with trophozoites scattered throughout the entire fish, it would seem that multi-infection on a large scale had taken place at approximately the same time. In specimens where a minute individual trophozoite was found there may have been mono-infection. In others, where minute as well as larger infections were present, there may have been multi-infection at different times, or sporoplasms from an older infection may have migrated and sited themselves at new locations.

We do not know whether or not complete immunity occurs. There is certainly no deterrent to the development of at least some infections into huge lesions. But it is apparent that the host reacts to some infections by an encapsulating process. Fischthal (1944) mentions this in his paper and we have observed such in our specimens; but relatively few encapsulated *Plistophora* were seen, and it is probable that this particular reaction of the host is not very significant except when the infections are small. Nigrelli (p. 199) suggests that phagocytic action takes place. There is only a slight suggestion that the host is refractory to *Plistophora* due to nematodes; much more material would have to be studied to obtain convincing data on this point (Table XIII). Yellow bodies (Table XIII, p. 135) were found next to the skin in numerous specimens; it is not known what the function of these bodies may be, but it is conceivable that they may be the result of a host's reaction to infections.

How is *Plistophora* transmitted? The answer to this question is highly problematical in view of the limited knowledge regarding the parasite's habits and its life cycle. The first question that may be asked is: how are the parasites liberated? In all probability most of them are set free when infected specimens die and decompose. But it is also possible that sporoplasms may leave a host through the di-

¹ Kudo (1924: 51, 52) lists *Plistophora typicalis* as being found in the following fish: *Blennius pholis*, *Cottus bubalis*, *C. scorpius* and *Gasterosteus pungitius*. Most of these fish, like *Macrozoarces americanus*, not only frequent the bottom, but probably exist among rocky areas to a great extent. Furthermore, in all instances the parasites were found in the muscle of the hosts.

gestive tract, gills or external surface. Predators may assist in releasing the spores or sporoplasms through their digestive tracts. What happens to the parasites after they leave the host body, and what their habits are when liberated, we do not know. They may exist free in the water, they may be associated with a vector, or they may have to pass through some phase of a cycle in an intermediate host. We do know, however, that spores were liberated in sea water (Nigrelli, p. 194) in the laboratory.

The parasite's entry to the host body is most likely made through the digestive tract, as suggested by Kudo (1931),¹ although it is also possible that parasites may gain entry through the gills. If sporoplasms enter the host through the gills, it is very likely that they are conveyed to the muscle through the blood. If they entered through some part of the alimentary tract, then they may be distributed 1) by the blood, 2) through the gut epithelium and body cavity directly to the flesh, or 3) by both of these methods. That they gain access to the flesh through the blood, as well as through the body cavity, seems most likely from our observations.

The data on infections anterior and posterior to the anus show clearly that a higher incidence of *Plistophora* appears in the muscle of the abdominal region than in that posterior to the anus. From a commercial point of view this suggests only that the anterior parts of the fillets are more likely to contain infections. On the other hand, these data do form the basis for a purely academic consideration of how the abdominal region becomes more heavily infected.

Although only a certain percentage of the total number of infections

¹ Kudo (1931) stated, regarding the order Microsporidia:

When such spores are taken into the digestive tract of a specific host, the polar filaments are extruded and perhaps anchor the spores to the gut-epithelium. The sporoplasms emerge through the opening after the filaments become completely detached. By amoeboid movements they penetrate through the intestinal epithelium and enter the blood stream or body cavity and reach their specific site of infection. They then enter the host cells and undergo schizogonic multiplication at the expense of the latter. The schizonts become sporonts, each of which produces a number of spores characteristic of each genus. Some spores seem to be capable of germinating in the same host body, and thus the number of infected cells increases. When heavily infected, the host animal dies as a result of the degeneration of enormous numbers of cells thus attacked. Such fatal infections may occur in an epidemic form, as is well known in the case of the pébrine disease of silkworms, the nosema-disease of honey bees, microsporidiosis of mosquito larvae, etc.

TABLE XV. DATA SHOWING NUMBER AND PERCENTAGE OF SPECIMENS WITH INFECTIONS DETERMINED ANTERIORLY, POSTERIORLY AND IN UNDETERMINED LOCATIONS. PERCENTAGES BASED ON NUMBER OF INFECTED SPECIMENS ONLY

Locality	Northern Cape Cod				Southern Cape Cod				Block Island				Long Island Sound	
	III/15/44		V/30/44		III/10-13/44		V/30/44		III/12/44		V/30/44		IV/6/44	
Date	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Number of specimens in sample.....	72	—	102	—	52	—	104	—	162	—	123	—	150	—
Total number of infected specimens.....	21	—	4	—	21	—	48	—	105	—	53	—	70	—
Specimens infected:														
on, above or anterior to anus.....	0	—	0	—	5	23.8	9	18.7	11	10.5	23	43.4	28	40.0
posterior to anus.....	0	—	0	—	1	4.8	9	18.7	4	3.8	13	24.5	5	7.1
both anterior and posterior to anus.....	0	—	1	25.0	2	9.5	3	6.3	14	13.3	9	17.0	4	5.7
anterior and posterior to anus and at undetermined location.....	0	—	0	—	2	9.5	2	4.2	7	6.7	3	5.7	2	2.9
mostly of undetermined location.....	21	100	3	75	11	52.4	25	52.1	69	65.7	5	9.4	31	44.3

TABLE XVI. ANTERIOR INFECTIONS VERSUS POSTERIOR INFECTIONS.
SPECIMENS FROM SEVEN HAULS (MARCH-MAY, 1944)

Specimens Infected Only Anterior to Anus

Number of Specimens	Size and Number of Infections per Specimen			
	Large	Moderate	Small	Minute
11*	1	—	—	—
2*	2	—	—	—
2	1	1	—	—
2	1	—	1	—
1	1	—	2	—
15	—	1	—	—
3	—	2	—	—
2	—	1	1	—
1	—	1	2	—
19	—	—	1	—
6	—	—	2	—
1	—	—	3	—
1	—	—	4	—
2	—	—	5	—
1	—	—	few	—
4	—	—	—	1
1	—	—	—	3
1	—	—	—	few
1	—	—	—	many

—
Total...76

Specimens Infected Only Posterior to Anus

7	1	—	—	—
1	3	—	3	—
9	—	1	—	—
1	—	2	—	—
13	—	—	1	—
1	—	—	2	—

—
Total...32

* In these tabulations the numbers listed in the columns under the "Size and Number of Infections" represent the infections *per fish*. For example, in the first line, one large infection was present in each of the 11 specimens; in the second line two large infections were present in each of the two specimens, etc.

were positively located as anterior and posterior to the anus (Table XV, pp. 144-151), those that were definitely sited were in no way selected and therefore should give a fair indication of the overall relative infections in these two body areas.¹ For the discussion, therefore, we

TABLE XVII. TABULATION OF SPECIMENS IN WHICH INFECTIONS WERE PRESENT BOTH ANTERIORLY AND POSTERIORLY. SPECIMENS FROM SEVEN HAULS (MARCH-MAY, 1944).

Number of Specimens	Size and Number of Infections per Specimen							
	Anterior				Posterior			
	Large	Moderate	Small	Minute	Large	Moderate	Small	Minute
3.....	1.....	—.....	—.....	—.....	1.....	—.....	—.....	—.....
2.....	1.....	—.....	—.....	—.....	—.....	1.....	—.....	—.....
1.....	1.....	—.....	—.....	—.....	—.....	—.....	1.....	—.....
2.....	3.....	—.....	—.....	—.....	1.....	1.....	—.....	—.....
1.....	4.....	—.....	—.....	—.....	1.....	—.....	—.....	—.....
1.....	5.....	—.....	—.....	—.....	7.....	1.....	1.....	—.....
1.....	6.....	—.....	—.....	—.....	3.....	—.....	—.....	—.....
1.....	1.....	2.....	—.....	—.....	1.....	—.....	—.....	—.....
1.....	1.....	3.....	—.....	—.....	—.....	1.....	2.....	—.....
1.....	1.....	4.....	3.....	—.....	—.....	2.....	2.....	—.....
1.....	2.....	1.....	—.....	—.....	1.....	—.....	—.....	—.....
1.....	3.....	2.....	—.....	—.....	1.....	—.....	—.....	—.....
1.....	—.....	1.....	—.....	—.....	1.....	—.....	—.....	—.....
1.....	—.....	1.....	—.....	—.....	—.....	1.....	—.....	—.....
3.....	—.....	1.....	—.....	—.....	—.....	—.....	1.....	—.....
1.....	—.....	1.....	—.....	—.....	—.....	—.....	—.....	1.....
1.....	—.....	1.....	1.....	—.....	—.....	—.....	1.....	—.....
1.....	—.....	1.....	1.....	—.....	—.....	1.....	—.....	—.....
1.....	—.....	1.....	2.....	—.....	1.....	—.....	—.....	—.....
1.....	—.....	1.....	2.....	—.....	—.....	1.....	—.....	—.....
2.....	—.....	—.....	1.....	—.....	—.....	—.....	1.....	—.....
1.....	—.....	—.....	2.....	—.....	—.....	—.....	1.....	—.....
1.....	—.....	—.....	4.....	—.....	—.....	—.....	—.....	some
1.....	—.....	—.....	1.....	few	—.....	—.....	1.....	—.....
1.....	—.....	—.....	—.....	2.....	—.....	—.....	2.....	1.....
1.....	—.....	—.....	—.....	many	—.....	—.....	—.....	many

Total 33

¹ As a further indication of the predominance of the incidence in the abdominal region, see Tables XVI, XVII. In the former are listed a total of 108 specimens with a tabulation of their infections: 76 showed *Plistophora* only anteriorly, while 32 had infections only posteriorly. In Table XVII are tabulated the infections of only those specimens which were infected both anteriorly and posteriorly. Of the

will confine our consideration to only the small, moderate and large infections which were definitely sited and exclude the minute ones. The total number located anterior to the anus was 257, posterior 122. The relative weight and volume of the fillets anterior to the anus was 20.6 per cent of the total weight of the fish, the posterior weight 27.2 per cent (footnote, p. 25). Theoretically, if the blood distribution is relatively the same in all parts of the muscle and if *Plistophora* has a preference for the muscle, blood should distribute the sporoplasms on an average in relatively the same proportions throughout the entire flesh of the animal. Also, we will consider that all of the parasites posterior to the anus have been distributed by the blood stream, and that those infections in the abdominal region might arise from sporoplasms in the blood stream as well as from those which pass through the gut epithelium and body cavity directly to the muscle. Therefore, considering that all infections posteriorly emanate from sporoplasms in the blood stream, which would be 122 infections for a 27.2 per cent volume of the flesh, then 92 infections for a 20.6 per cent volume of flesh would arise from the blood stream anteriorly. The balance of 165 infections anteriorly would presumably gain entrance to the flesh directly through the gut epithelium and body cavity, this being roughly 64 per cent of the anterior infections only.

Obviously this estimation does not take into consideration numerous questionable factors, such as infections which probably arise from older well-established concentrations in the muscle, host reactions, regional preferences such as *Trichinella* has for particular muscles, the blood distribution which may influence the incidence in the anterior part of the fish, etc.

That the blood stream does enter into the distribution seems quite certain, considering the uniform distribution of trophozoites throughout the muscle of *some* specimens, but if the blood distributes all of the sporoplasms, then there is probably some peculiarity which results in a much higher percentage of infections in the anterior muscle. If auto-infection takes place sporoplasms from older infections may spread more generally anteriorly, with a smaller number of sporoplasms passing to the posterior muscle. The preponderance of infec-

33 specimens thus infected, 22 have larger and more numerous infections in the abdominal region, 3 posteriorly and 8 have infections approximately equal in both areas. In these two tables are excluded all infected specimens which had one or more infections of a questionable location.

tions in the anterior part of the fish may suggest that the parasite has a preference for this location, but since infections were found only in the posterior part of a number of specimens, this would seem highly improbable. Unless the sporoplasm has a peculiar preference for distribution by the blood stream, and since the sporoplasms must enter into the blood stream and cells by amoeboid movement, there seems little reason to suppose that these amoeboid organisms cannot pass through the gut epithelium and possibly through the body wall directly to the flesh.

The size-range of infected fish. The data indicate clearly that the younger fish were proportionately less infected than the older ones, and that infections were more numerous and larger in the older fish (Table XVIII, Fig. 23, pp. 144-151).¹ In regard to the proportion of infected versus uninfected fish, using the term "infected" to mean anything from a single trophozoite to multiple lesions, Fig. 23 shows the percentage of infected and uninfected specimens at each 5-cm. length interval in each sample from different localities. Thus in sample E from Block Island the 60-cm. interval (57.5-62.5 cm.) contained 21 per cent of the specimens in the sample infected and 9.5 per cent uninfected. In other words, 30.5 per cent of the total sample fell in this length group, of which over two-thirds were infected.

If we look at the proportions of infected versus uninfected fish at each 5-cm. length interval it is apparent: a) that at the lower levels there were more uninfected than infected specimens;² b.) that at the intermediate and higher length intervals there were more infected than uninfected fish, with the highest percentage of infected fish in each sample tending to fall at the intermediate length intervals, where there were the most fish. This, of course, does not obtain in cases where the total percentage of infection is low (*e. g.*, northern Cape Cod.)

These data point to several interesting considerations. First, they

¹ Sandholzer, *et al.*, also noted a correlation between the degree of infection and the age, using Clemens' age determinations on Bay of Fundy fish for specimens for southern New England.

² Note that few specimens, or none at all, below 50 cm. were taken in some samples. However, in the Long Island sample numerous specimens below 50 cm. were taken, and it is clear that the proportion of infected versus uninfected specimens was low among the smaller fish. A similar pattern would be expected if greater samplings had been obtained in the lower size categories of other collections (see p. 83 for discussion of selective sampling by the trawl nets).

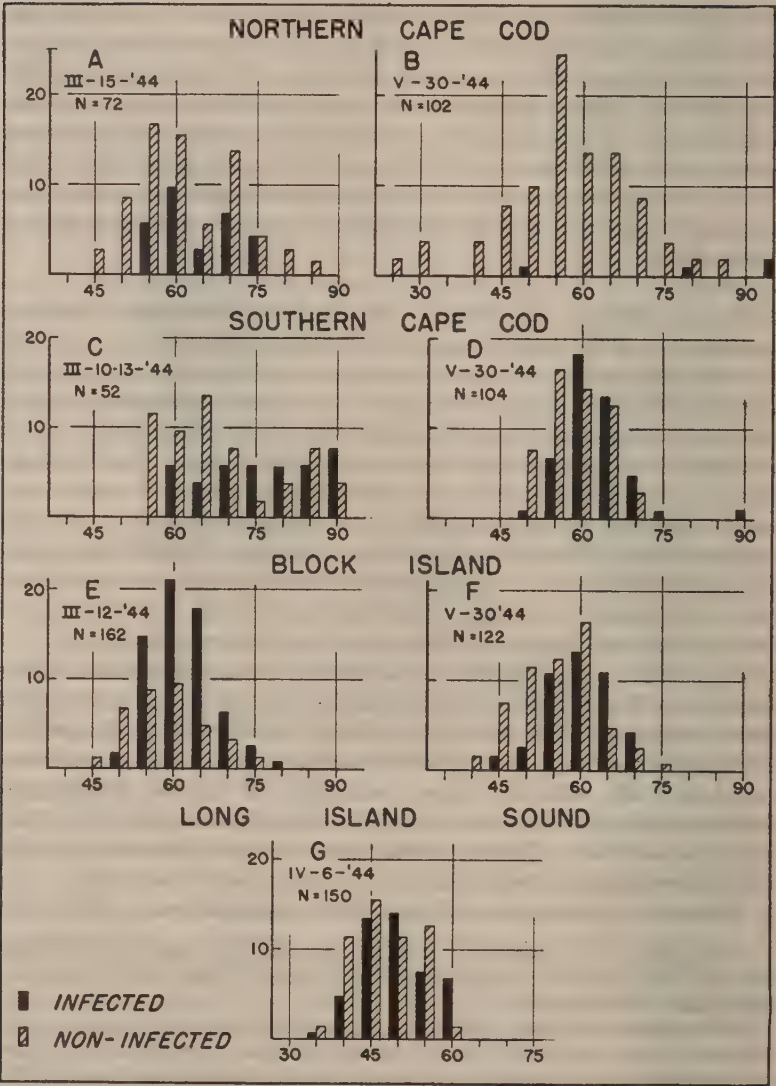


Figure 23. Ocean pout infected and uninfected with *Plistophora macrozoarcidis* tabulated by 5-cm. length intervals, expressed in per cent of sample. One specimen omitted from E and F (footnotes, pp. 148, 149).

TABLE XVIII. SPECIMENS OF INFECTED AND NON-INFECTED OCEAN POUT TABULATED BY 5-CM. LENGTH INTERVALS
(SEE FIG. 22)

5-cm. Length Inter- vals	Northern Cape Cod						Southern Cape Cod						Block Island						Long Island Sound			5-cm. Length Inter- vals		
	III/15/44			V/30/44			III/10-13/44			V/30/44			III/12/44			V/30/44			IV/6/44					
	I	%	N	I	%	N	I	%	N	I	%	N	I	%	N	I	%	N	I	%	N			
25	0	—	0	0	2	2.0	0	—	0	0	—	0	0	—	0	0	—	0	0	—	0	25		
30	0	—	0	0	4	3.9	0	—	0	0	—	0	0	—	0	0	—	0	0	—	0	30		
35	0	—	0	0	0	—	0	—	0	0	—	0	0	—	0	0	—	0	1	0.7	2	35		
40	0	—	0	0	4	3.9	0	—	0	0	—	0	0	—	0	0	—	0	7	4.7	17	40		
45	0	—	0	0	8	7.8	0	—	0	0	—	0	0	—	0	0	—	0	20	13.3	23	45		
50	0	—	6	8.3	1	10	9.8	0	—	1	1.0	8	7.7	3	1.8	2	1.6	9	7.4	20	13.3	50		
55	4	5.6	12	16.7	0	—	25	24.5	0	—	6	11.5	7	6.7	17	16.3	3	2.5	14	11.5	21	55		
60	7	9.7	11	15.3	0	—	14	13.7	3	5.8	5	9.6	19	18.2	15	14.4	8	7.3	13	10.7	15	60		
65	2	2.8	4	5.6	0	—	14	13.7	2	3.8	7	13.5	14	13.5	13	12.5	8	4.9	13	10.7	6	65		
70	5	7.0	10	13.9	0	—	9	8.8	3	5.8	4	7.7	5	4.8	3	2.9	10	6.2	5	3.1	5	70		
75	3	4.1	3	4.1	0	—	4	3.9	3	5.8	1	1.9	1	1.0	0	—	4	2.5	2	1.2	0	75		
80	0	—	2	2.7	1	1.0	2	2.0	3	5.8	2	3.8	0	—	0	—	1	0.6	0	—	0	80		
85	0	—	1	1.4	0	—	2	2.0	3	5.8	4	7.7	0	—	0	—	0	—	0	—	0	85		
90	0	—	0	—	0	—	4	7.7	2	3.8	1	1.0	0	—	0	—	0	—	0	—	0	90		
95	0	—	0	—	2	2.0	0	—	0	—	0	—	0	—	0	—	0	—	0	—	0	95		
Total	21	29.2	51	70.8	4	4.0	98	96.0	21	40.5	31	59.5	43	46.2	56	53.8	105	64.8	57	35.2	70	57.4	80	53.2

I—Infected specimens

N—Non-infected specimens

indicate that the infections develop into larger lesions over a long period of time and probably into more lesions of a smaller size, that perhaps the intermediate sized fish are more susceptible to initial infection, or that both of these conditions obtain. We believe that the fish probably live for years while infected with *Plistophora*, and that the infection is not generally contracted as readily by younger fish as by the older, probably because of differences in their habits; *e. g.*, the sharp teeth of the young, as compared with the blunt worn teeth of older specimens, suggest different feeding habits.

The second consideration is that infection by *Plistophora* is not a significant cause of premature mortality. If this were so we would expect to find the uninfected specimens dominant at the upper length intervals, which is not the case. Therefore, we believe that the infections are not usually the cause of premature mortality, although they may enlarge and increase in numbers (in the same fish) and probably persist throughout the life of the individual. The fact that we have not seen any evidence that the spores are liberated through the skin of living ocean pout is a further indication that the infection is of long duration.

A third possibility is also suggested by the data in Fig. 23. The most apparent change in the proportions of infected and uninfected fish (from *less* infected than uninfected to *more* infected than uninfected) occurs in general at the intermediate length intervals from 50 to 65 cm. Although this is not so in all the samples, and although the data are insufficient to settle the point conclusively, it appears that dominance of infected over uninfected fish, once established at the intermediate length intervals, does not tend to become more dominant at the higher length intervals. If true, this might mean that the older and larger fish were less susceptible to infection than the individuals of small and intermediate size. It would also suggest that an equilibrium between the infected and uninfected fish was reached, either because of the lower susceptibility of larger ocean pout, or because of increased mortality among the larger infected specimens. There is a strong suggestion in these data that such an equilibrium is attained.

The incidence in relation to sex, vertebral counts, etc. All collections but one showed relatively the same percentage of infection for males as females (Fig. 22).¹ The only exception was the May sample from

¹ Sandholzer, *et al.*, found "no apparent difference in the degree of parasitism be-

southern Cape Cod, in which about 27 per cent of the males were infected as compared to about 55 per cent of the females. However, this uneven distribution of infections by sex may be due to the uneven sampling of the sexes (76 females and only 26 males). The incidence was also tabulated against vertebral counts, but no correlation seemed to be apparent.

Sandholzer, *et al.*, stated:

A correlation seemed to exist between the size of the lesion and the degree of infection. In areas where the incidence of parasitism ranged from 27 to 33 percent, the majority of the lesions were 15 mm. or over in diameter, whereas in areas where the incidence was below 27 percent, most of the lesions were under 15 mm. It was also observed that in zones of high incidence, multiple lesions were present in most of the parasitized fish, but single lesions predominated in specimens taken from waters where the lower incidence prevailed.

It is not clear to us whether these authors meant the majority of *all* lesions in the entire infected sample, or the majority of lesions in *each* infected fish. At any rate, our data do not support these conclusions, for we are unable to find a correlation between the size of the lesions and the incidence per sample. If we consider all *Plistophora* infections from minute to large in all the infected fish of a sample (*i. e.*, all infections of the entire sample) we obtain the results given in the following table.

Sample	Incidence in per cent of sample	Total Number of Infections	
		Large and moderate	Small and minute
A.....	4.....	3.....	2.....
B.....	29.....	0.....	23 + (4)*
C.....	40.....	14.....	44 + (2)*
D.....	43.....	58.....	63.....
E.....	46.....	28.....	54 + (6)*
F.....	47.....	16.....	109 + (5)*
G.....	64.....	130.....	145 + (11)*

* + in final column indicates many additional infections which are not included in the total; these trophozoites were too numerous to count, and they can only be indicated. The figures in parentheses show the number of specimens which contained trophozoites too numerous to count.

tween sexes. However, individual catches occasionally showed a higher parasitic incidence in one or the other of the sexes."

It will be noted that only the sample with the lowest incidence of four per cent contained more than 50 per cent of the large and moderate infections, while in all other samples the majority of the infections were small or minute. If we consider the number of specimens infected with one or more large or moderate lesions as compared with those having only minute or small infections, we find that there appears to be no correlation with the incidence in this case either.

Sample	Incidence in per cent of sample	Approximate Percentages of Infected Specimens with only:	
		Large and moderate <i>Plistophora</i>	Small and minute <i>Plistophora</i>
A.....	4.....	50.....	50.....
B.....	29.....	0.....	100.....
C.....	40.....	50.....	50.....
D.....	43.....	50.....	50.....
E.....	46.....	40.....	60.....
F.....	47.....	25.....	75.....
G.....	64.....	50.....	50.....

It will be seen that in no sample was the percentage of specimens with one or more large or moderate lesions greater than those with only minute or small infections.

Single and multiple lesions¹ were found in specimens from all collections of all localities. Whether or not there is a correlation of single lesions with a low incidence or multiple lesions with a high incidence we do not know. Such determinations would require more data, but it appears that such a correlation is unlikely.

Sample	Incidence of <i>Plistophora</i> in per cent of sample	Number of Specimens with Single Infections	Number of Specimens with Multiple Infections
A.....	4.....	3.....	1.....
B.....	29.....	12.....	9.....
C.....	40.....	7.....	14.....
D.....	43.....	26.....	26.....
E.....	46.....	25.....	23.....
F.....	47.....	36.....	34.....
G.....	64.....	32.....	73.....

¹Single lesion here means one infection of any size per specimen; multiple means two or more of any size per specimen.

Seasonally the incidence varied within the same general area, such as that of northern Cape Cod or Block Island (Table XVIII, Fig. 23), but we have no data which determine conclusively whether or not the incidence varies from time to time at a given location within a general area. All of our collections were taken at different locations. However, we believe it is very likely that a varying incidence would be found at different times in the same location. Explanations for these variations in the incidence have not been found, but they are unquestionably complex. No doubt local populations, which probably exist in an area such as northern Cape Cod, move from one place to another in search of optimum conditions in response to stimuli such as temperature, food, spawning urge, *etc.*; a case in point being the annual movements to and from the commercial fishing bottoms (p. 110). The incidence of *Plistophora* in these populations probably varies, and these movements may be at least a partial explanation for the differences which were obtained in our samples. Also, a certain amount of intermingling of populations may take place.

On the basis of vertebral counts, it has been pointed out that regional populations exist (p. 115), and this viewpoint is further substantiated by the data on *Plistophora* as well as the nematodes. The St. Andrew's fish appear separate from those of northern Cape Cod because of the abundance of nematodes in the former (60%) and the relatively small number in the latter (13% on an average for March and May). Furthermore, the northern Cape Cod specimens, with a relatively low *Plistophora* count, are set apart from those of southern New England.¹ Although the populations in the three southern New England areas are not as clearly separable from each other as those mentioned above, the specimens from within Long Island were smaller and less heavily infected than those of Block Island and southern Cape Cod, thus sug-

¹ Sandholzer, *et al.*, stated:

"The lowest incidence was observed off the southern shore of New Jersey and increased in the more northerly water. Extensive sampling in the area from the eastern end of Long Island to Nantucket showed that parasitized fish comprised from 4½ to 38 percent of those examined, the greater number of infected fish being taken from the deeper water. The areas of lowest infection were those adjacent to Block Island and in Muskeget Channel."

Our studies do not include ocean pout from New Jersey waters, but our findings do indicate that the incidence was lower at northern Cape Cod than in the southern New England areas, where a comparatively high incidence was found adjacent to Muskeget Channel and Block Island.

gesting that they represent a separate population. The southern Cape Cod and Block Island stocks seem to be separate, but the evidence from the incidence of *Plistophora* does not appear to support such a contention.

In what situations are the infections likely to be contracted? In the Accounts of the Data (pp. 144-151) it was noted that the minute whitish trophozoites were fairly abundant in January and were no longer apparent in the May collections. This seems to indicate that sporoplasms gain entry to the fish on a larger scale at one time of the year than at another. If the sporoplasms gained access to the muscle in the same relative amounts at all times of the year we would expect to find the minute light trophozoites in all other samples on more or less the same scale as in January, but such is not the case. Therefore, we believe that a higher period of infection may be likely in the fall of the year among rocky areas. The ocean pout presumably spends a larger part of its life in rocky areas, like other blennies, with a probable resultant higher mortality and subsequent liberation of spores in these locations. Also, it is in these areas that the ocean pout spawns in the fall, at which time it probably leads its most sedentary existence. Also, at this time it is largely dependent on the food available among the rocks, and it is possible that a vector may be more abundant on these situations.

Although no secondary host has been found for a microsporidian, this does not necessarily preclude the possibility of there being one. As pointed out earlier, infections may be contracted haphazardly, but it is also possible that the incidence is linked to some factor such as the feeding habits, possibly on certain types of bottom and at a certain time of year. If a vector exists it must be available to the host to a certain degree in all areas where the actual infection takes place, seemingly more so in some locations than in others when we consider the varying incidence. The thermal and other physico-chemical conditions, the degree to which the vector might maintain or support the parasite for transmission to the host, the size and abundance of the secondary host and the frequency with which it is eaten, may also have a bearing on the parasitization. From a consideration of the stomach contents (Table XII, pp. 118-131) we are able to find no positive answers to the numerous problems mentioned above; but we are able to obtain at least some indication of what organisms might

serve as a possible secondary host for microsporidians and for other parasites of the ocean pout.

First, if we consider each area as a separate entity, we find that the most likely possibilities from northern Cape Cod appear to be the Gammaridae, *Ophiura robusta*, *Echinarachnius parma*, *Pecten magellanicus*, *Aphrodita hastata*, the decapods, *Cardium pinnulatum* and *Unicola*; in the southern Cape Cod area there are the Gammaridae and *Echinarachnius parma*, *Aphrodita hastata* and *Cancer irroratus*. The Block Island area stomach contents suggest the Gammaridae, *Unicola*, the Caprellidae, *Echinarachnius parma* and *Cancer irroratus* as well as *Cardium pinnulatum*, *Pecten magellanicus*, Tunicata and Nudibranchiata. The most likely from Long Island Sound would be *Yoldia limulata* and *Cancer irroratus*. In an overall consideration, including St. Andrews, New Brunswick, the Gammaridae are the most prevalent generally, following which are *Unicola*, *Cancer irroratus*, *Echinarachnius parma*, *Cardium pinnulatum*, *Aphrodita hastata*, *Yoldia* and *Pecten* species.

Does Plistophora macrozoarcidis manifest itself in epidemic form? As indicated by Kudo (footnote, p. 156) it is not uncommon for some Microsporidia to appear in epidemic form. The data available here are insufficient to answer this question in relation to the ocean pout, but the problem of fluctuation in the incidence of infection deserves further consideration in the future. From an economic point of view this factor might be of the greatest significance, especially if the incidence diminished, for the fish might then be marketed more readily without the deterrent factors which are inherent at present.

We have noted that previous workers (p. 138) made no mention of the parasite; furthermore, this microsporidian was not discovered by any parasitologists or other workers previous to 1943, although other parasites were observed in the ocean pout (Nigrelli). This indicates that the parasite may be recent in this fish. However, from our data it is clear that at present the incidence is generally high in some areas while relatively low in others, and that it even varies within these areas. If the parasites develop slowly, as has been suggested (p. 164), and do not create a sudden change in the mortality of a population within a year or two, it seems unlikely that the infection would manifest itself in acute epidemic form. On the other hand, it is possible that long range increases and decreases in the incidence may take

place. Such changes might result from any number of causes. For example, the host's reactions to the infection may vary; the availability of the parasite, whether free or in relation to a vector, may change and may be related to the mortality of infected hosts with the subsequent liberation of parasites by decomposition; or the concatenation of a variety of environmental factors which are conducive to parasitization may have a bearing on the incidence.

CONCLUSIONS

The original objectives of this study on the biology and economic importance of the ocean pout were twofold—to provide information for the rational utilization of the stock by investigation of the life history, catch records, abundance, *etc.*, and to add to our knowledge of the parasites with particular reference to their effect on the marketability of the fillets and the seasonal and geographical incidence of infection. Such a study, while placing emphasis on the applied aspects, almost inevitably includes matters whose implications are in the field of pure and theoretical biology. The present work often drew us far from our primary objectives, and as is so frequently the case, it has opened up a series of new problems for subsequent investigation. We have made no effort to separate the “pure” from the “applied” results in the text; indeed we believe that the two are inseparable in any study of adequate breadth, and that they are mutually dependent on each other so that no clear line of division is possible or practicable. For example, the description of a new species of parasite, the interpretation of its life cycle, the mode and duration of infection, *etc.*, may be considered as pure biology; but when that parasite manifests itself in such form as to affect the marketability of ocean pout fillets, this information then becomes of the utmost practical importance. Similarly, the use of length-weight curves of the separate sexes as a means of determining the average age at maturity, the interpretation of length-frequencies or of vertebral counts, are primarily problems in theoretical biology; but when the matter of optimal utilization of the stock is considered, it then becomes of practical significance to know when this species first spawns, how fast it grows, as well as the age composition and racial make-up of the commercial catch. The abstract at the beginning of this paper presents a brief

summary of our conclusions; the present section confines itself to the immediate objectives that prompted us to undertake this study.

Problems involving the rational utilization of a stock of fish of a particular species are extremely complicated. For their solution it becomes necessary to provide estimates of the magnitude and age composition of the population, the production and survival of young in successive years under varying conditions, the natural and artificial mortality of the stock as a whole as well as of its different age categories, growth rates and rate of replacement from below, migratory habits and a host of other matters. To add to the difficulties already inherent in such problems, work is not usually undertaken until the supply has given some indication of diminution so that there is cause for alarm; seldom does the biologist have the opportunity to observe the stock from the inception of the fishery. Seldom also are adequate catch statistics available, so that the tools which are essential to the completion of work are not ready for immediate use. It is small wonder, therefore, that these problems are slow of solution.

We have shown that the catch of ocean pout in 1943-1944 would have been considerably higher had it not been for a variety of factors which reduced the landings. While there is no way of estimating what volume the annual catch might reach under conditions of a more intensive fishery, there is good evidence that the stock is capable of producing much more than 5,500,000 pounds *per annum*. The consistent level at which the landings might be *maintained* is beyond conjecture in the present state of our knowledge; this can be determined only as subsequent exploitation takes place, since we have no estimate of the total magnitude of the stock. However, the seasonal nature of the fishery affords this species a rather high degree of protection. The population is not subject to the inroads of the commercial fishery in the period before, during and immediately after reproduction; in other words, there is no opportunity for the fishery to concentrate on spawning fish to the detriment of over-all productivity. Furthermore, the shape and nature of this species, contrary to many others, assures the escape of a large proportion of the young from the trawl net so that the mortality of the smaller size categories as a result of the fishery is apparently negligible. We have no evidence as to what proportion of the total stock leaves the summer and fall rocky habitat in December and January, but there is some indication that the majority of the younger fish remain there during their first years,

and it is possible also that some of the adults stay there. In all events, a combination of circumstances which involve the seasonal movements, life history, general shape and hardiness assures this fish a degree of security in relation to the operations of trawlers and draggers that is unusual. For these and other reasons it appears that there is little to be feared in fishing the stock more intensively than at the level which gave rise to the 1943-1944 catch.

Careful and continued observation of the landings and the age composition of the catch should be maintained as a check against the future possibility of over-fishing, not only to safeguard the industry, but also since such investigation would provide a continuous record of man's exploitation of the stock from the beginning of a fishery of major proportions. Particularly should such observations be made because this is not a species in which the phenomenon of year-class dominance (the production of exceptionally large numbers of young in any one year) can reasonably be expected to occur. In other words, it is extremely unlikely that the stock would get occasional sudden increments from unusually large year-classes, as with species whose reproductive potential is extremely high. If the fishing mortality became too high, and if the spawning stock were reduced to such a level that its sum total productivity suffered, the slow growth rate of this species would cause two particular difficulties. First, it would take the stock a long time to recover since replacement by increased numbers of young would be slow. Second, the result of the reduction of the spawning stock, *i. e.*, diminished productivity, would not be obvious at first and would take a number of years to manifest itself. For these reasons it is especially important that the age composition of the catch, the total landings, and the return per unit of effort should be subject to close and continuous scrutiny. Only in this way can subsequent development and expansion of this fishery be safeguarded adequately.

We have also indicated previously that, apart from other considerations, the ocean pout fishery is important because the major landings are made in the winter and early spring months; this is a period when the available quantity and variety of fresh fish are relatively small, and when the demand is high. For these and other reasons cited in the section on Economic Considerations, it seems clear that every effort should be made to overcome the marketing problems stemming from the parasites of this fish.

In regard to the protozoan parasite, *Plistophora macrozoarcidis*, which is responsible for the "sores" in the flesh, there is no evidence that it, or any other member of the group to which it belongs, ever parasitizes a warm-blooded host; therefore, the chances of actual infection of man appear to be negligible. Furthermore, feeding tests and other evidence provide no indication of serious illness from the consumption of flesh which harbors this parasite. The fact that ocean pout have been eaten for generations by fishermen and others without apparent detriment, and that the fillets enjoyed such wide sale in 1943-1944, is further indication—albeit of a negative sort—of its innocuity. However, more stringent feeding tests should probably be undertaken, not only as an extra precautionary measure, but also because of their value in discussion with uninformed skeptics.

Another problem involves the effect of the parasite on the marketability of ocean pout fillets. We have already emphasized the necessity for *quality* products in the fisheries industries, and it is clear that the sale of fillets which occasionally have prominent lesions is detrimental, not only to the marketing of that particular species, but also to the trade as a whole. Imperfect ocean pout fillets did appear on the market in 1943-1944 and were in turn partly responsible for the curtailment of the fishery. Our own observations show that candling (examination by transmitted light) as practiced commercially was inadequate for the elimination of unclean fillets. However, we believe that more careful candling and improved technique would be feasible, and that a clean and acceptable quality product could then be marketed. We need not dwell on the absolute necessity of rigorous inspection of this and all other fisheries products, for its paramount importance to the industry is obvious. In the case of the ocean pout it is clear that this species should *never* be sold "in the round" and that the careful candling of *skinned* fillets is essential in order to insure a clean product.

It has been reported by other workers that infections by *Plistophora* spread and increase in size in frozen fillets in storage; even if this is accepted as fact, it is not necessarily detrimental to the marketing of ocean pout. Our own evidence indicates that the small infections (individual trophozoites which might not be detected in commercial candling) do *not* increase in size or spread in frozen fillets; since the moderate and large infections should be eliminated by proper inspection, their behavior in frozen flesh is of little or no concern in practice.

The successful marketing of clean ocean pout fillets is therefore primarily dependent on efficient candling; this method of examination is practiced successfully with other species which present similar problems, and there seems to be no reason why it cannot be applied to the ocean pout.

Indeed, there is incontrovertible evidence from the course of the fishery in 1945 that clean ocean pout fillets can be marketed successfully and without detriment to the trade under proper conditions. Our own investigations have shown important differences in the incidence of infection in ocean pout from various localities. Thus, the number of large infections was consistently low in fish from northern Cape Cod (Provincetown) as opposed to those from areas to the south and west; it was in the Provincetown area that the fishery continued to operate in spite of the 3-cent ceiling (which was not consistently maintained¹), after the embargo in February 1945 in New York City had reduced the landings in New Bedford and other ports to relatively low levels. As a matter of fact, the landings at Provincetown during March, April and May 1945 totalled 412,500 pounds, as against 160,000 pounds in the same three months in 1944. Our studies show further that the Provincetown ocean pout, although having a low incidence of large infections, possessed many individual trophozoites. It seems clear, therefore, that the small infections are inconsequential. The primary problem is to be certain that no fillets with moderate or large infections are marketed.

We believe that every incentive should be given to the fishery off northern Cape Cod to continue and to expand. The standards of commercial candling should be raised, and, once they are perfected, there seems to be no reason why the fishery in all southern New England waters should not proceed with the development begun in 1943-1944—always, however, under conditions of careful inspection and constant observation.

¹ For example, see U. S. Fish and Wildlife Service Market News Service, May 2 and 22, 1945 (p. 1).

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¹ Abbreviations used in this bibliography taken whenever possible from "A world list of scientific periodicals published in the years 1900-1933," Oxford Univ. Press, London.

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STUDIES ON THE MARINE RESOURCES OF
SOUTHERN NEW ENGLAND

V. PARASITES AND DISEASES OF THE OCEAN
POUT, *MACROZOARCES AMERICANUS*

By
ROSS F. NIGRELLI

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New York Aquarium

New York Zoological Society

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ABSTRACT

Protozoan parasites recorded from the ocean pout (*Macrozoarces americanus*) are: *Sarcocystis* sp. Fantham and Porter (1943), (Sarcosporidia); *Ceratomyxa acadiensis* Mavor (1914), (Myxosporidia); *Chloromyxum clupeiidae* Hahn (1918), (Myxosporidia); and *Plistophora macrozoarcidis* sp. nov. (Microsporidia). *Sarcocystis* and *Ceratomyxum* were not found in this study. *M. americanus* is a new host record for *C. clupeiidae*, which, together with *P. macrozoarcidis*, is found in the flesh. The latter induces large tumor-like growths affecting the marketability of the fish. The morphology, cytology, life history, pathogenesis and toxicity of *P. macrozoarcidis* are discussed.

The helminthic parasites are: *Cryptocotyle lingua* (Creplin, 1825), (Trematoda); *Bothrimonus intermedius* Cooper (1918a), (Cestoda); *Porrocaecum decipiens* (?) (Krabbe, 1878), (Nematoda); *Contracaecum macrozoarcium* sp. nov., (Nematoda); and *Echinorhynchus gadi* Zoega, 1776 (Acanthocephala). All the parasites except *B. intermedius* were found in the present survey. The larval parasites *C. lingua* and *P. decipiens* (?) affect the marketability. *C. lingua* may possibly infect humans since they have been observed naturally and experimentally in mammals; they are metacercarial and are found encysted predominantly in the skin of ocean pout, although other larval trematodes, which may or may not be the larvae of *C. lingua*, were present in the flesh. *M. americanus* is also a new host record for *C. lingua*. The adults of *P. decipiens* have been reported from the intestine of marine mammals; whether or not they can infect land-living mammals has not been determined. *Contracaecum macrozoarcium* sp. nov. is found in the intestine of ocean pout; a detailed description is given.

A new species of ichthyobdellid leech, *Platybdella buccalis* sp. nov., found in the mouth of a single specimen, is described.

A fibro-epithelial growth, predominantly fibrous in nature and present on the snout of one ocean pout, is reported and the probable causes of its growth are discussed. No copepods have been recorded for this host, although they have been reported in other members of the family (Zoarcidae).

I. PROTOZOAN PARASITES, WITH SPECIAL REFERENCE TO *PLISTOPHORA MACROZOARCIDIS*, SP. NOV., AN INTRAMUSCULAR MICROSPORIDIAN

The sporozoan parasites described in this paper and reported by other investigators, except for *Sarcocystis* sp., belong to the order Cnidosporidia. All species discussed are listed in Table I. The most important parasite encountered, for reasons reported elsewhere in these studies (pp. 132-170), is the microsporidian *Plistophora macrozoarcidis* sp. nov., which induces large tumor-like lesions of the muscle. The parasite has been reported recently by Fischthal (1944) and Sandholzer, Nostrand and Young (1945) as a species of *Ichthyosporidium* on the basis of a tentative identification made by the author of this paper. This contribution deals with a description of *P. macrozoarcidis*, together with a description of each of the other protozoan parasites recorded from North Atlantic ocean pout.

TABLE I. PROTOZOAN PARASITES OF *Macrozoarces americanus*

Parasite	Author	Year	Infected Organ	Locality
PHYLUM: Protozoa				
CLASS: Sporozoa				
SUBCLASS: Acnidosporidia				
ORDER: Sarcosporidia				
SPECIES: <i>Sarcocystis</i> sp.	Fantham & Porter	1943	Muscle	Canada
SUBCLASS: Cnidosporidia				
ORDER: Myxosporidia				
FAMILY: Ceratomyxidae				
SPECIES: <i>Ceratomyxa acadiensis</i>	Mavor	1914	Gall bladder	Canada
FAMILY: Chloromyxidae				
SPECIES: <i>Chloromyxum clupeiidae</i>	Hahn	Present Paper	Body muscle	North Atlantic
ORDER: Microsporidia				
FAMILY: Nosematidae				
SPECIES: <i>Plistophora macrozoarcidis</i>	Nigrelli	Present Paper	Body muscle	North Atlantic

1. ACNIDOSPORIDIA

Sarcocystis sp.

Sarcosporidia are parasites of reptiles, birds and especially mammals. Recently, Fantham and Porter (1943) recorded such sporozoans from Canadian fishes. The organism found in *Macrozoarces americanus* was not specifically designated. The parasites were found in small numbers in smears made of soft muscle taken from a fish which was bought in a shop in Montreal. They report that Miescher's tubes, about one mm. long, were present. The spores measured up to 15 microns in length, although most of them were between 6 and 10 microns, with a maximum breadth of 3.5 microns. Metachromatic granules were present at the more pointed end, and a distinct nucleus was seen in some of the spores.

No such spores were encountered in our material. Structures resembling Miescher's tubes were common, but these were interpreted as "cylinders" of muscle fibers containing developing trophozoites of *Plistophora macrozoarcidis*.

2. CNIDOSPORIDIA

Ceratomyxa acadiensis Mavor, 1914

Mavor (1914, 1916) reported the myxosporidian, *Ceratomyxa acadiensis*, from the gall bladder of Canadian ocean pout and other

marine fishes. Members of the genus *Ceratomyxa* are characterized by lateral prolongation of the spore; shell-valves conical and hollow, attached on bases; sporoplasm usually not filling intraporal cavity. Mavor reported that the vegetative form of *C. acadiensis* was polymorphic and disporous in sporogony. The spores were wide, short and slightly compressed dorso-ventrally, with very long fine lateral filaments. The polar capsules were spherical, but the polar filaments were not visible in the fresh unextruded state. The spores measured 40–50 microns in breadth; diameter along the sutural line 7–8 microns; diameter of the polar capsule 3–4 microns; length of the polar filaments 70 microns; length of the lateral extensions of the spore case 250–300 microns.

Chloromyxum clupeiidae Hahn, 1918

(Plate I A, B, C)

Members of the genus *Chloromyxum* are myxosporidians possessing four polar capsules. The majority of species are coelozoic, occurring principally in the gall bladder of marine and fresh water fishes. However, a few have been reported as histozoic, particularly invading muscle tissue. The form found in *Macrozoarces* resembles in many respects *C. clupeiidae* Hahn (1918) from *Clupea harengus* and other marine fishes. It also shows certain similarities to *C. funduli* Hahn (1915), a species infecting *Fundulus heteroclitus*. This is not surprising since it is very difficult to make a distinction between *C. clupeiidae* and *C. funduli*. It should be pointed out that *C. clupeiidae* was seen and recorded by Linton (1901), who turned over the material to Tyzzer for further study. Kudo (1919) had the opportunity to examine the slides prepared by Tyzzer and a comparison of Kudo's description of *C. clupeiidae* with the form present in *Macrozoarces* shows close agreement.

The *Chloromyxum* from *M. americanus* are intramuscular parasites producing a hyalin degeneration of the muscle fibers involved. However, the degeneration is not as extensive as that caused by *Plistophora*, a microsporidian also infecting muscle fibers of the ocean pout. A mixed infection of both types of cnidosporidians often occurs; the two types cannot be distinguished from each other by the candling method suggested by Fischthal (1944). However, with the aid of a hand lens, and after a certain amount of experience, one may be able to distinguish the two types of infection, although final diagnosis must be made

microscopically. The nodules produced by *Chloromyxum* are whitish and invariably small, measuring about 0.3 mm. in diameter, and may reach a length of approximately 2 mm. On the other hand, the trophozoic masses of *Plistophora* are often yellowish in tint and the organisms are more malignant, showing greater invasive characteristics. A section through one of the *Chloromyxum* infected nodules is shown in Plate I A. This figure shows the parasites in a late stage of development in which most of the sporozoans are in the pansporoblastic phase of the cycle. This is an interesting feature, indicating that a single infection is involved. Other muscle fibers may show earlier or later stages of development. A smear of mature spores is shown in Plate I C. Plate I B is from a smear showing immature spores with capsulogenous and sporoplasmic nuclei.

The details in the early stages of development were not studied in this species, although multinucleate trophozoites occasionally were seen. The majority of the material studied was in various stages of sporogony. This species is monosporoblastic. The mature spores were studied from iron-haematoxylin stained smears shown in Plate I C. As may be seen from this figure, the spores when viewed from the top (anterior end) are somewhat quadrilateral in form. The sides and basal parts of spore, however, are round. The spore case is exceptionally thin and not distinct from the sporoplasm. The latter stains intensely with haematoxylin, and is uninucleate. The polar capsules are pyriform with capsulogenous nuclei often persisting. The filaments were indistinct and none were seen extruded. The spores measure about five microns in length and seven microns across the anterior end.

Plistophora macrozoarcidis sp. nov.

(Plates II-V; Text Figures A, B)

Plistophora macrozoarcidis is a microsporidian, the sporont of which develops into a variable number of sporoblasts, each of which becomes a spore. More than 16 sporoblasts may be formed in the process of sporogony. Other species have been reported from fish (Kudo, 1924, Doflein, 1928 and Bond, 1937, 1938). The type species is *Plistophora typicalis* Gurley (1893) from the muscle of *Cottus bubalis*, *C. scorpius*, *Blennius pholis* and *Gasterosteus pungitius*.

P. macrozoarcidis is an intramuscular parasite inducing large tumor-like masses (Plate II A, B), measuring in some instances up to eight

or more centimeters. They are found more often in the deeper body muscle and are especially abundant in the regions of the vertebral column. The growths have never been seen in the ulcerative condition, *i. e.*, broken through the skin, as may occur in some of the nodule-producing myxosporidians (Nigrelli and Smith, 1938). It is not known how the spores are liberated. They may be set free in the process of being eaten by predators (although it does not seem likely that this fish is as subject to predation as many others), or they may be liberated only after the death of the host and its subsequent decomposition.

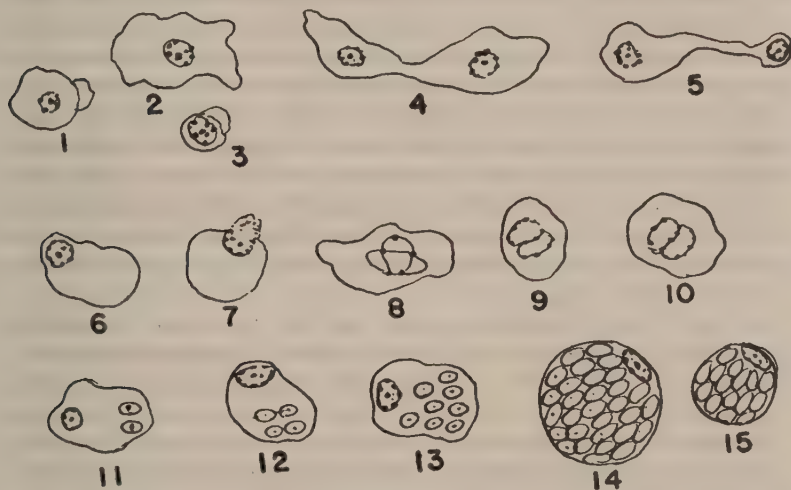
The larger tumor-like masses can sometimes be recognized by bulges on the body. The lesions are usually exposed by filleting and with the aid of a hand lens the smaller trophozoites may be seen scattered here and there in the muscle fibers. When the larger masses are cut, a pus-like exudation often occurs. Microscopical examination of this substance shows numerous spores and granular debris.

Life History. When the parasite was first examined, the organism was tentatively identified as an haplosporidial form and it was indicated that it might be a species of *Ichthyosporidium*. This conclusion was reached because of the large size of the tumor-like masses as well as the fact that the spores did not shoot out filaments when subjected to techniques usually employed for this purpose. However, after studies of sectioned and stained preparations it was established that the parasite was a microsporidian. A restudy of fresh spores verified this interpretation. *Mature spores* were recognized eventually and polar filament extrusion was successfully accomplished.

The stages in the life cycle of most species of *Plistophora* are not clearly understood, although they have been assumed to be similar to those reported for other microsporidians. Schizonts and pansporoblasts are easily recognized in sectioned and stained preparations, but details leading to the formation of these bodies have not been described heretofore for species of *Plistophora* from fishes.

It is assumed that the portal of entry is through the intestinal mucosa; uninucleate trophozoites (planonts) emerging from the spore pass through the gut wall and migrate to the muscle tissue of the body. These amoebulae invade the fibers, penetrating the sarcolemma. Here they undergo reproduction by binary or multiple fission producing more uninucleate forms now referred to as schizonts (Plate III A;

Text-Fig. A 1-5). The schizonts in turn invade adjacent regions of the muscle syncytia and continue the process of schizogony. These early stages are manifest macroscopically as minute whitish cylinders, the smallest of them measuring about 0.5 mm. in length, lying end to end along the long axis of the fibers (Plate II A). The presence of numerous such bodies scattered here and there indicate that a multiple infection may be involved. The schizonts vary considerably in size.



Text Figure A. Stages in the development of *Plistophora macrozoarcidis* ($\times 800$). 1-5 Schizonts; 6-10 Development of the pansporoblasts (6 Nucleus at the periphery of the cell; 7 Throwing off of chromatin; 8 Division to form binucleate stage; 9, 10 Fusion of nuclei to form the synkaryon); 11-15 Sporogenesis.

The nucleus is deeply basophilic, but chromatin granules can be differentiated, particularly in active dividing forms. There is no evidence of true mitosis.

Eventually each schizont undergoes a series of nuclear changes involving (1) a throwing off of chromatin material (Text Fig. A 6, 7), (2) a nuclear division which produces a binucleate cell (Text Fig. A 8), (3) a nuclear fusion to form the synkaryon (Text Fig. A 9, 10) and subsequently the pansporoblast. The latter, by repeated nuclear division, gives rise to a variable number of sporoblasts, each of which develops into a spore. Pansporoblasts in various stages

of sporogony are shown in: Text Fig. A 11-15; Plates III B, C; IV A, B; V A. The pansporoblast increases in size and the sporoblastic nuclei are developed successively, first two, then four, eight, sixteen, etc. However, the transformation of the sporoblast into the spore could not be followed. Eventually, the entire pansporoblast is filled with spores surrounded by a fairly resistant membrane, forming a "cyst" which measures from 15-30 microns in diameter (Text Fig. A 14, 15; Plate IV A); it will be noted also from this figure that the cysts occupy practically the entire mass of muscle bundles, and that although hyalinization has set in the fibers are intact. The spores in such cysts are immature, being for the most part still in the pansporoblastic stage containing developing sporonts. Macroscopically this stage is manifest as larger white bodies. However, such pansporoblasts continue to grow at the expense of the host tissue. Plate IV B shows how extensive the degeneration of the host tissue may be in this late stage of development. It is at this stage that the mature spores are found, and the tissue containing them is brownish and more or less granular in texture.

An interesting phenomenon noted, and one which may be new in the cycle of these microsporidians, is a division of the mature pansporoblasts as shown in Plate V A. The significance of this process is not understood.

A large number of spores, at this stage of development, are free, and many of them are highly refractive, indicating the absence of any internal structure. Among these spores, spore cases, and pansporoblasts may be found uninucleate cells typical of schizonts. Some of these are in the process of division. It is believed that these are the result of sporulation, and that auto-infection is taking place. The developing schizonts spread out along the interfibrous pathways and infect adjacent areas of the muscle to start the cycle again.

*The Spore.*¹ As stated above, mature spores are found in lesions containing the hard granular material. By mature spores is meant those spores which can be made to release their polar filaments. When bits of the brown granular substance are placed in sea water whether or not pressure is applied numerous spores are released which

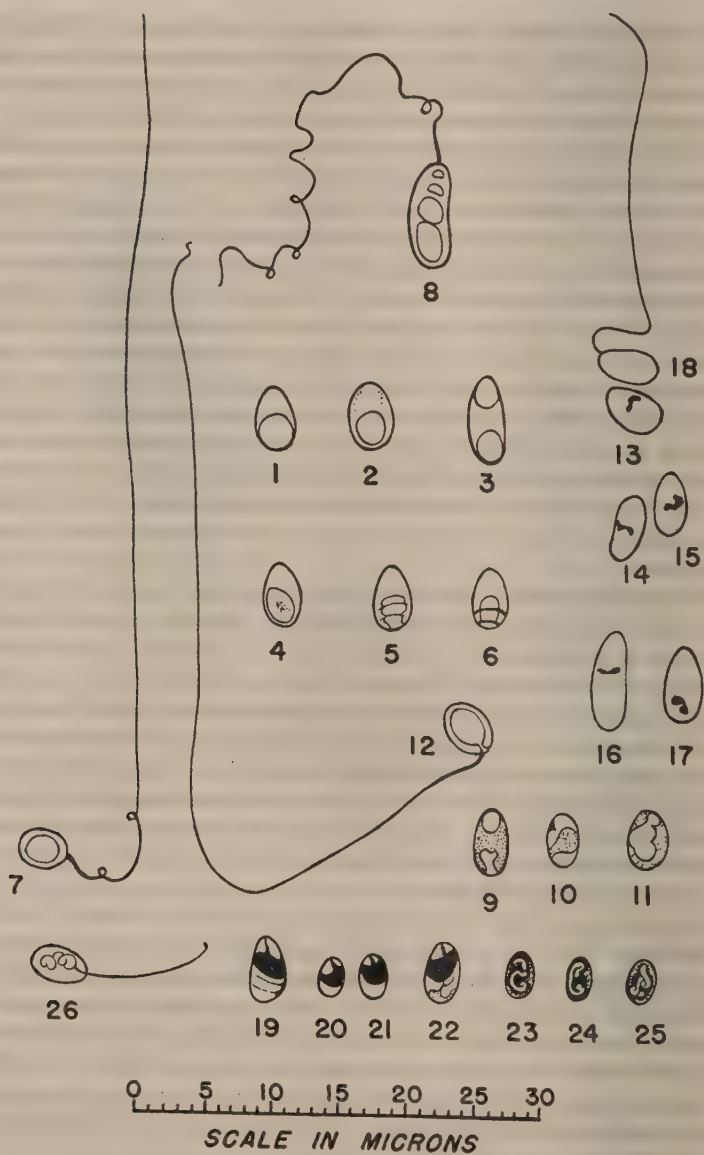
¹ We wish to express our thanks to Grace E. Pickford of the Bingham Oceanographic Laboratory, Yale University, for her studies on the spores which are included in this section.

can be seen to undergo violent discharge of the filaments. The soft white bodies release spherical cysts containing developing spores which are similar to those found in the brown bodies, but evidently these are not mature since they cannot be induced to extrude the threads.

Unstained live spores, examined under immersion lens, are variable in size but usually oval in shape (Plate V B; Text Fig. B). They measure from 3.5–5.5 microns in length. A few sausage-shaped spores were encountered which measured up to eight microns in length. This dimorphic nature of microsporidian spores is not unusual, but its significance is not definitely known. The spores have been regarded by some as micro- and macrospores, indicating a sexual phase. Others believe that the difference in size is due to the number of spores developed by the sporont; the smaller the number the larger the size (Kudo, 1924, 1930). In the present case, pansporoblasts with varying numbers of sporonts do occur and may account for the size variations found. However, although two distinct kinds of spores were found, no differences in the internal structures were noted. The larger spores also could be made to release their polar filaments under proper conditions.

The spore capsule is uniform in thickness and highly refractive. It is smooth and apparently structureless. Insofar as could be determined, it is composed of a single piece, as is found in most microsporidians (Monocnidea). The unstained, undischarged spore shows a clear space (vacuole) at the wider posterior end (Text Fig. B 1, 2). In some cases, both ends show these clear areas (Text Fig. B 3). Careful examination of the vacuole demonstrates the presence of a spiral structure, which is even more evident in spores placed in distilled water (Text Fig. B 5, 6). These observations indicate that the clear area is the polar capsule. It should be pointed out that the sporoplasm is indistinct in the living spore.

The extrusion of the polar filaments is a violent process. As the threads are "shot" out, the spores apparently rebound and spin. They may spin away from the filaments which become attached to other spores or entangled in debris. After the discharge the vacuole seems to occupy the entire spore case (Text Fig. B 12); a varying amount of material remains at the narrower (anterior) end, at the point of the discharge. Whether or not this material represents the sporoplasm could not be determined. Complete or partial discharge of spores may take place in distilled or salt water and the process is not



TEXT FIGURE B. (Explanation on opposite page.)

accelerated or induced in refractory material by the addition of hydrochloric acid, acetic acid or iodine placed under the coverslip. The iodine stains the filaments which are already discharged, but it will not cause the extrusion. This is not surprising, since it is well known that different species of microsporidians react differently to the various chemicals usually employed for this purpose. Threads stained with iodine are thicker at the basal than at the distal ends (Text Fig. B 7, 8, 12) and measure about 70 microns in length. It is the opinion of most investigators that the polar filaments in microsporidians are uniform in thickness throughout the entire length, except in the genus *Mrazekia*. In this group, however, the structure of the spores and filaments are different, for the thickened basal end (manubrium) is quite distinct from the finer distal part. Whether or not the filament in *P. macrozoarcidis* is tubular was not determined.

As mentioned above, no sporoplasm was seen to emerge after the discharge of the filament, although a blob of refractive material could be demonstrated in the iodine-stained preparations at the point where the filament was extruded. This may or may not be the sporoplasm. Spores stained with aceto-carmin or aceto-orcin show a faintly pink-staining mass near the middle of the spore; this is usually absent following the discharge (Text Fig. B 13-17). This would indicate that if the mass is the sporoplasm, it was discharged at the time of extrusion of the polar filament.

Smears of the material containing spores were fixed in Schaudinn's with acetic acid and stained with iron-haematoxylin. Some were counterstained with carbol-fuchsin. Eosin was found to be unsatisfactory as a counterstain for these spores. In such fixed and stained spores, the undischarged ones (Text Fig. B 19-22) show a central,

Explanation of Text Figure B. (Drawings by Grace E. Pickford.) 1, 2 Untreated, unexploded spores as they appear when first examined in sea water or distilled water; typical appearance with one "vacuole" at wide end. 3 Same, with two "vacuoles." 4 Same, showing faint structure within "vacuole"; ill-defined cloud often seen. 5, 6 Same after a few minutes in distilled water, with definite spiral structure in "vacuole." 7 Typical appearance of a discharged spore; thread slightly thicker proximally, but otherwise no structure observed. 8 Same, partial discharge of a large spore. 9-11 Undischarged spores after treatment with iodine. 12 Discharged spore showing aperture after iodine. 13-17 Undischarged spores after prolonged treatment with aceto-carmin; nucleus stained pink. 18 Typical discharged spore, after aceto-carmin; no nucleus. 19-22 Undischarged spores shown with Schaudinn-acetic, iron haematoxylin. Deeply stained central band of sporoplasm and slender thread or channel leading to apex. Occasional faint structure in "vacuole." 23-25 Undischarged spores, treated as above, sometimes show a highly refractive coiled tube inside. 26 Partly discharged spore, from fixed stained smear. No sporoplasm or nuclear material remains. Sporoplasm never seen in fully discharged spores.

darkly-staining mass with a line of similarly stained material leading towards the anterior end. The contents in the posterior part of the spore were often vague, but in some instances it was suggestive of a spiral (Text Fig. B 19). In certain spores the filaments were highly refractive, appearing as if filled with air (Text Fig. B 23-25).

The stained discharged spores never appear to contain the sporoplasm (Text Fig. B 26). When the appearance is to the contrary it is due either to the folding of the wall causing refractive indentations or to incomplete extrusion of the filament. In the latter, parts of the spiral thread are seen tightly coiled within the spore case, while a correspondingly shorter portion may be extruded.

Such observations of the stained spores suggest that the sporoplasm may be "shot" out before the thread, or simultaneously with it. If it moved out afterwards, by its own activity, one should find an occasional spore in which the planont could still be seen. On the other hand, if the planont is shot out one would expect to find amoeboid forms among the debris in the smear. It is difficult to say whether or not certain small objects seen in these preparations may be the released planonts.

Discharged spores with open anterior ends are seen rarely, but never when the thread remains connected; they are probably formed when the filament is torn away.

Comparisons. *Plistophora* have been reported from several species of marine fishes. However, it is very difficult to make comparisons since most of the investigators failed to report any detailed information which would distinguish their species from those previously recorded. Insofar as is known, *P. macrozoarcidis* differs from those species recorded from the muscle of marine fishes in the following ways: (1) size and shape of the pansporoblast, (2) size and shape of the spore, (3) length of the polar filament, (4) factors which will induce polar filament extrusion, (5) host, (6) size of the lesion induced by the parasite, and (7) geographical distribution.

Pathogenesis. Cnidosporidians are parasites of invertebrates and cold-blooded vertebrates. The host reactions to these Protozoa are manifest in many ways, from the production of simple cysts to hyperplastic growths of the tissues involved. In most cases, however, the reaction is merely a process involving tissue destruction. The para-

sites grow at the expense of the host. This action is especially evident in the case of infection with *P. macrozoarcidis*. Wherever the parasite infiltrates there is a complete hyalinization and destruction of muscle, eventually only granular debris remaining. Phagocytic activity of host cells is quite evident. Occasionally the host lays down a protective layer of fibrous connective tissue and this at times may be so extensive as to appear hyperplastic (Plate V C). There is very little inflammatory reaction involved.

Although many foci of infection may occur in any one fish in relatively distant parts of the body indicating a multiple infection, it appears that sporulation *in situ* is possible and that the planonts may migrate along the intermuscular or interfibrous pathways and set up new centers of schizogony and sporogony. Whether or not the organisms will grow and reproduce at freezing temperatures, as indicated by Sandholzer, Nostrand and Young (1945), was not determined by us. These investigators reported that microsporidian lesions increase in size and number at temperatures as low as -13° C., and that non-infected fillets placed in contact with infected ones became parasitized at this low temperature. It is obvious that these organisms are capable of growth and reproduction at comparatively low temperatures under conditions of the normal winter habitat of ocean pout, but if the experiments of Sandholzer, *et al.*, prove to be true, then these protozoans must have protoplasm that is very different from that in ordinary plants and animals, and even from that found in some psychrophilic bacteria which can grow and reproduce at 0° C.

Toxicity. The question as to whether or not cnidosporidians elaborate toxic substances has never been settled. Kudo (1924) refers to this problem only slightly. In our studies, glycerine extract or saline suspension of spores injected intraperitoneally into mice and rats demonstrated no toxic effects. Spores fed to mongrel dogs passed through the gastro-intestinal tract seemingly unchanged, with no visible effects to the animals other than the production of increased amounts of mucus in the stools. Sandholzer, *et al.*, reported no ill effects to cats and pigs. The results of post-mortem examination of cats and pigs sacrificed following the feeding of infected ocean pout material was summarized for these workers by Dr. D. R. Coburn, Veterinarian in charge of the Patuxent Wildlife Disease Research Laboratory, as follows: "Post-mortem examinations and histological

study of representative tissues did not reveal the presence of any pathological change attributable to the fish feeding." However, these experiments do not preclude the possibility that the organisms or the fish proteins denaturized by the enzymatic action of the parasites may be toxic to humans.

SUMMARY

1. Four species of sporozoans are reported from ocean pout (*Macrozoarces americanus*) from the North Atlantic. Three species occur in the muscle and one in the gall bladder.

2. With the exception of *Sarcocystis* sp. reported by Fantham and Porter (1943), all the organisms belong to the subclass Cnidosporidia. Of the myxosporidians, *Ceratomyxa acadiensis* Mavor (1914) is recorded from the gall bladder, while *Chloromyxum clupeiidae* Hahn (1918) is reported for the first time from the muscle of the ocean pout.

3. A new species of intramuscular microsporidian, *Plistophora macrozoarcidis*, is described. Macroscopically the parasites are recognized as white or buff to brown colored bodies lying along the long axis of the muscle fibers. In some fish these infections involve large numbers of fibers which in certain instances collectively give the appearance of a massive tumor-like growth. Microscopically, the smaller white bodies contain developing schizonts; the larger white bodies are usually filled with schizonts and immature pansporoblasts; the buff or brown bodies contain mature pansporoblasts filled with ripe spores.

4. The life-history of *P. macrozoarcidis* seems to be as follows. The trophozoites penetrate the sarcolemma and undergo reproduction by binary or multiple fission producing numerous uninucleate schizonts; the schizonts in turn invade adjacent regions of the muscle syncytia and continue the process of schizogony. Eventually, each schizont undergoes a series of nuclear changes which involve the throwing off of chromatin material, a nuclear division resulting in a binucleate cell, a nuclear fusion to form the synkaryon and subsequently the pansporoblast. The pansporoblast increases in size and the sporoblastic nuclei are developed successively until sixteen or more such bodies are formed. However, the transformation of the sporoblast into spores could not be followed. It is assumed that the portal of entry is through the gastro-intestinal tract and the planont released from the spore makes its way to the body muscle. There is some evidence that auto-infection may take place.

5. A detailed description of the spore and polar filament extrusion is also reported. The latter is accomplished in sea or distilled water even when no pressure is applied.

6. The pathogenesis and toxicity of these organisms are discussed.

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II. ON *CONTRACAEUM MACROZOARCIUM*, SP. NOV., WITH SPECIAL REFERENCE TO *PORROCAECUM DECIPIENS* (?) (KRABBE, 1878) AND OTHER HELMINTHIC PARASITES

An outstanding feature of the helminthic fauna of *Macrozoarces americanus* is the paucity of the trematodes. It is possible that they have been overlooked, but an intensive search in 25 specimens of ocean pout in this laboratory failed to uncover a single fluke other than the larval form of *Cryptocotyle lingua*. Further, insofar as is known, no trematodes have been reported by other investigators who have had the opportunity to examine ocean pout for parasites. The indication is, then, that these fish must be especially resistant to infections by trematodes, even by those numerous species that apparently show no host specificity. A similar condition was reported by Markowski (1939) in his studies on the helminthic forms of *Zoarces viviparus* from the Baltic. This investigator reported one species of fluke (*Gyrodactylus medius* Katherina, 1894) from the gills of this host. The internal helminths of *Z. viviparus* consist of: three species of cestodes (*Caryophyllaeus* sp., juv., from the gut; *Trienophorus lucii* from liver and body cavity; *Bothriocephalus* sp. from the gut); four species of nematodes (*Cystidicola skrjabini* from the gut; *Raphidascaris* sp., larvae, from liver and gut; *Contracaecum aduncum* from gut and body cavity; *Contracaecum* sp., larvae, from the gut); five species of acanthocephalans (*Corynosoma strumosum* from the body cavity and *Echinorhynchus gadi*, *E. salmonis*, *Pomphorhynchus proteus* and *Neoechinorhynchus rutili* from the intestine).

Table II lists the helminthic parasites found in the American ocean pout. The metacercarial form and the larval nematode found in the flesh are especially important since they might affect both the marketability and edibility of the fish.

TABLE II. TAXONOMIC TABLE OF THE HELMINTHIC PARASITES OF
Macrozoarces americanus

Parasite	Author	Infected Organ
PHYLUM: Platyhelminthes		
CLASS: Trematoda		
SUB-CLASS: Digenea		
ORDER: Prosostomata		
SUB-ORDER: Distomata		
SUPERFAMILY: Heterophyoidea		
FAMILY: Heterophyidae		
SPECIES: <i>Cryptocotyle lingua</i> (Creplin)	Present Paper	Skin
CLASS: Cestoidea		
SUB-CLASS: Cestoda		
ORDER: Pseudophyllidea		
SUPERFAMILY: Bothriocephaloidea		
FAMILY: Diphylobothriidae		
SPECIES: <i>Bothrimonus intermedius</i> Cooper	1918a Clemens, 1921	Intestine
PHYLUM: Nematelminthes		
CLASS: Nematoda		
ORDER: Euenematoda		
SUPERFAMILY: Ascaroidea		
FAMILY: Heterocheilidae		
SUB-FAMILY: Anisakinae		
SPECIES: <i>Porrocaecum decipiens</i> (?) (Krabbe)	Present Paper	Muscle
<i>Contracaecum macrozoarcium</i> sp. nov.	Present Paper	Intestine
<i>Contracaecum</i> sp. (?) (possibly <i>macrozoarcium</i>)	Present Paper	Intestine
CLASS: Acanthocephala		
FAMILY: Echinorhynchidae		
SPECIES: <i>Echinorhynchus gadi</i> Zoega	Linton, 1933 Present Paper	Intestine

1. TREMATODA

Cryptocotyle lingua (Creplin, 1835)

Cryptocotyle lingua is a digenetic trematode, the metacercariae of which are found in several species of marine fishes of the North Atlantic coast (Linton, 1940). This is the first time the parasite has been reported from the ocean pout. As in all fishes infected with the parasite, the larvae are recognized as minute black cysts on the fins and skin. Insofar as is known these larval flukes have never been found in the *flesh* of the various hosts from which they have been recorded. According to Stunkard (1930):

From the evidence available it would appear that the cercaria invades the mucous covering of the fish . . . Once invasion is accomplished, the cercariae may encyst almost immediately; more often, however, they migrate through the connective tissue until they reach some skeletal structure, either a scale or fin ray, where encystment occurs.

He stated further,

As the larva, now termed a metacercaria, grows larger the cyst increases in size . . . The metacercaria enlarges faster than the cyst and bends on itself to form a J- or U-shaped larva. Meanwhile, the mesenchymatous tissue of the fish has formed a strong connective-tissue capsule around the primary cyst which cannot increase further in size. Consequently, the larva, which fills the cyst completely, can grow no larger. It may persist in this condition for long periods of time, perhaps years.

However, metacercarial cysts are also of common occurrence in the flesh of the ocean pout. Whether or not they are the larvae of *Cryptocotyle* is still uncertain. The fact that the latter are present in the skin would lead one to assume that they may be the same. The ocean pout is a soft bodied form and it is possible that the parasites, if they are *C. lingua*, may migrate deep into the flesh before they become encysted. To establish this with certainty, the worms first must be liberated from the cysts, and detailed observations must be made on the excretory system and its pattern determined and compared with that found in previously described larvae of *Cryptocotyle*. Liberating the worms from the cysts is not a simple process since the host membranes forming part of the covering are tough, and the worms are often injured in the process of dissection. Stunkard (1930) obtained excellent material for study by subjecting the cysts to artificial gastric and intestinal enzymes.

The metacercarial cysts in the flesh of *Macrozoarces americanus* are minute, light or dark in appearance. They measure about 0.1–0.2 mm. in diameter. Sectioned and stained preparations show the presence of an encysted worm. The oral sucker is clearly visible and there is no indication of an acetabulum, the absence of which is typical of the metacercariae of *C. lingua*.

The capsule is especially thick and in some at least devoid of any pigmentation in contrast to the cysts seen in the skin, which are invariably surrounded by host melanophores or melanin-bearing cells which are massed around the encapsulated organisms. Such a condition has never been reported, insofar as is known by us, in flesh-inhabiting trematode larvae, as for example in the case of *Clinostomum marginatum* (found in the flesh of many species of fresh-water fishes). Hunter (1941) attempts to account for such differences by postulating that deposition of melanin in cells surrounding the cysts of the metacercariae may result through the action of a chromogen which is

brought in by the parasite, the host cells possessing the necessary enzyme for this reaction. However, parasites like *Clinostomum* may lack the necessary chromogen. At any rate, it is our belief that the presence or absence of pigmentation is one of location. In most instances, the larvae of *Cryptocotyle* encyst in the corium of the host tissue where melanophores are of great abundance; the melanated cells around the cysts may be melanophores or they may be massed macrophages heavily laden with melanin granules. The presence of the latter at sites of infection in fish is a common host reaction. In the case of *Clinostomum* larvae and some metacercarial cysts in the flesh of the ocean pout, the lack of pigmentation may be attributed simply to the absence of these melanin-bearing cells.

If the metacercariae found in the flesh prove to be different from those found in the skin of the ocean pout, then its life history also must be established. It is very likely that it would follow the same pattern reported for *C. lingua*, the cycle of which was determined by Stunkard (1930). The adult of this species normally becomes sexually mature in the intestine of terns and sea-gulls. The parasite belongs to the family Heterophyidae, about which Stunkard stated:

So far as known, all members of the family have a common life history, and the cercariae when they escape from the snail encyst in fishes, being transferred passively to their vertebrate hosts when the infected fish are eaten. One peculiarity of this group of trematodes consists in the fact that they have little specificity in regard to their final hosts . . . All species, insofar as they have been investigated, may develop to maturity in the common laboratory animals, cats, dogs, rats, rabbits, guinea-pigs, etc. Four have been proved experimentally infective for man and presumably all are potential human parasites.

It should be pointed out that *C. lingua* has been reported as occurring naturally in certain fish-eating mammals. Stunkard and Willey (1929) established experimental infection in kittens and mice. Willey and Stunkard (1942) reported similar results for dogs, showing that the pathology resulting from this infection is manifest by a denudation of the epithelium of the mucosa, production of large amounts of mucus, sloughing of tissue, hyperemia, and even a hyperplasia of the tissue elements involved.

2. CESTODA

Bothrimonus intermedius Cooper (1918a)

This is a pseudophyllidean tapeworm first described by Cooper (1918a) from the intestine of the flounder, *Pseudopleuronectes americanus* and redescribed by him in 1918b. The same investigator (1921) reported the parasite from *Macrozoarces americanus*. On the basis of this identification it was also recorded by Clemens and Clemens (1921). The parasite was not found in fish studied in this survey.

3. NEMATODA

Nematodes found in ocean pout belong to the order Ascaroidea, family Heterocheilidae, subfamily Anisakinae. Such worms are characterized as being stout in body and possessing a head with three large lobes or lips; alimentary canal with post-oesophageal ventriculus, and/or oesophageal or intestinal diverticula; cuticle not provided with spines or raised structures (Yorke and Maplestone, 1926). The generic and specific distinctions are based on the nature of the digestive tract (Baylis, 1921) and the lip structures.

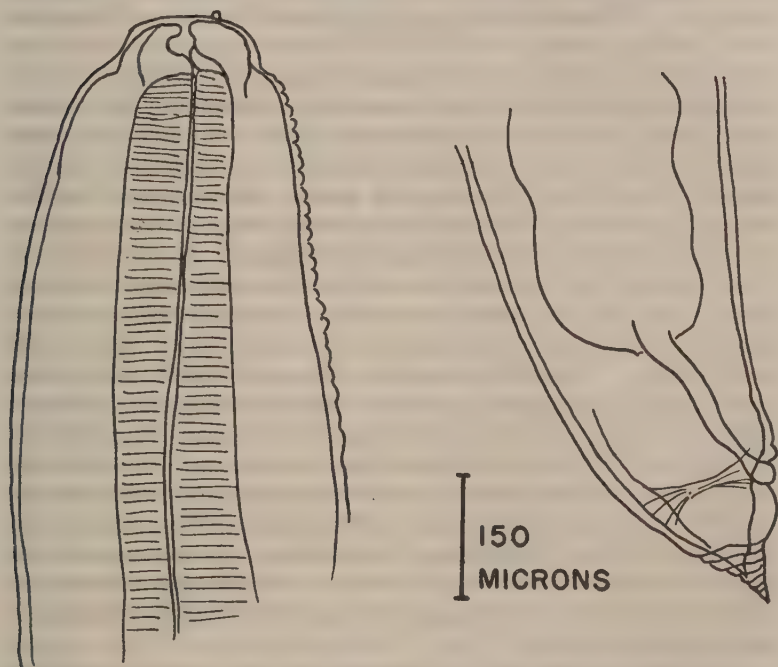
Porrocaecum decipiens (?) (Krabbe, 1878)

Plate VI, Text Figure C

Many species of larval nematodes have been reported from marine fishes of the American coast of the North Atlantic (Linton, 1901). The descriptions in most instances are incomplete and, consequently, it is very difficult to classify the worms. Earlier workers described the larval nematodes either under the name "Agamonema," which has no generic value, or under the name *Ascaris*, a term which is now used to designate those worms that infect land living mammals. This confusion was noted by Baylis (1916) and by Walton (1927). The latter worker pointed out that "The group *Agamonema capsularia* (*Ascaris capsularia* Rud. 1802 *sen. str.*) has been the recipient of many encapsulated larval Ascarids, usually from aquatic hosts, and undoubtedly of several different species." A similar opinion was held by Baylis (1916), but after a careful study of encapsulated worms from several fish species, he defined the limits which encompassed the parasites that could strictly be called *Ascaris capsularia*. In his report, Baylis indicated that *A. capsularia* was the larval form of *A. decipiens* Krabbe, sexually mature ascaroids found in the intestine of

marine mammals. Kahl (1939) is of the same opinion. However, it should be noted that the evidence for this conclusion is circumstantial and as yet no experimental data has been offered to substantiate this interpretation. Baylis (1921) later allocated the sexually mature *Ascaris decipiens* to the genus *Porrocaecum* Railliet and Henry.

The larval nematodes embedded in the flesh of the ocean pout are



Text Figure C. Anterior and posterior parts of *Porrocaecum decipiens* (?) Krabbe.

in all probability *Porrocaecum decipiens*. A species of nematode infesting the flesh of Canadian ocean pout was reported by Clemens (1920). The parasite was examined by the late Maurice C. Hall, who considered it a species of *Kathleena*, and it was later reported as such by Clemens and Clemens (1921). Hall further suggested that the worm might be a new species. Whether or not we are dealing with the same worm has not been determined, but it is our belief that the two are identical. However, there are certain differences between our specimens and *A. capsularia* described and figured by Baylis (1916),

especially in the nature of the lip structures and the posterior end. The similarities in the size and relationships of the several parts of the intestinal tract are striking even though Baylis' description is a composite one, *i. e.*, it is derived from specimens taken from different hosts. The absolute and relative size of these structures (oesophagus, ventriculus and caecum) has been and still is used for the diagnostic characters. We agree with Baylis (1916) and Dollfus and Desportes (1945) that the caecum is a highly variable organ and its size has no species value. In the case of the oesophagus and ventriculus, Baylis shows that the length of these structures is correlated to a certain degree with the length of the worms. The ventriculus (posterior oesophagus) is less plastic, attaining a maximum length (1.2 mm.) in worms of larger size (28 mm. or 38 mm.). He concludes from this that the ventriculus "does not continue to increase in size in proportion to the growth of the individual." In general, our measurements of the worms from the ocean pout fall within the expected variation given by Baylis for *Ascaris capsularia*. Our size range is slightly narrower, extending from 11–25 mm. in length and from 1.5–2.3 mm. in width. The cuticle is smooth, the anterior end is more or less round, and a boring tooth, typical of the larval ascaroids of fishes, is present. The lip is typically trilobed, but it should be noted that although the lip structures of these larval worms may be used to distinguish one form from another, they cannot be used for referring the parasites to any one adult species. The oesophagus averages in size about 2 x 0.2 mm.; ventriculus 1.3 x 0.3 mm. The caecum is highly variable measuring from 0.51 to 1.2 mm. This variation is not correlated with the size of the nematodes, since even small caecae may be found in larger worms.

The giant excretory cell characteristic of the forms designated as *Ascaris capsularia* and *Porrocaecum decipiens* was not observed, although the photograph of the worm (Plate VI) shows what may be its duct ending between the two rudimentary ventro-lateral lips.

The anal opening lies about 0.15 mm. from the posterior extremity, the latter terminating as a small spike-like tip that appears to be retractile.

If the form found in the flesh of the ocean pout is the same as *A. capsularia* and therefore the larval stage of *Porrocaecum decipiens*, then the adults may be expected to occur in the intestinal tracts of marine mammals, as indicated above. Whether or not the worms can

infect land inhabiting mammals, including man, has never been determined. Feeding experiments should be carried out to establish this point since it has been suspected that other nematodes of fishes do infect these forms.

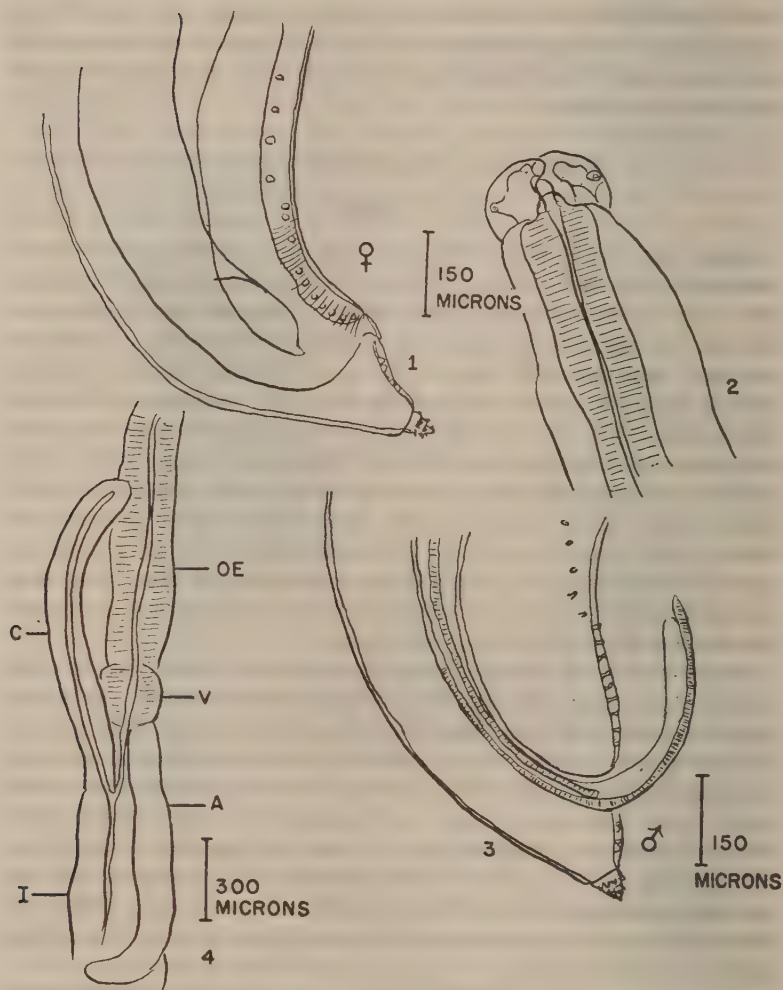
Contracaecum macrozoarcium sp. nov.

Text Figure D

Ascaroids in the stomach of ocean pout belong to the genus *Contracaecum* Railliet and Henry, 1912 (= *Kathleena* Leiper and Atkinson, 1914) (see Yorke and Maplestone, 1926). They are partly characterized by the presence of an oesophageal appendix and an intestinal caecum. Again similar worms were noted by Clemens and Clemens (1921); these were also identified by Hall as a species of *Kathleena*. Our studies show that at least one of the worms in our collection, *Contracaecum macrozoarcium*, is new. These are stout reddish worms found in comparatively large numbers in the gastro-intestinal tract of ocean pout. Both immature and mature males and females were found. The males are smaller, measuring 15–28 mm. in length and about 0.25–0.70 mm. in width. The females measure from 26–45 mm. in length and from 0.5–1.5 mm. in width. The uteri of the larger females are filled with thin shelled eggs.

Measurements of other structures are given in Table III. In both sexes the cuticular covering of the body is finely striated. The head end is truncate with typical lip structures, the nature of which can best be determined by examining Text Fig. D. The tail in both sexes is retractile and the cuticular covering at the tip is raised in minute spines, much like that reported by Chandler (1943) for *Contracaecum habena* (Linton), a common ascaroid from the toadfish, *Opsanus tau*. The spicules of the male *C. macrozoarcium* are sub-equal and the extended portions measure 0.31 and 0.39 mm. in length. There are about 12–14 pairs of pre-anal papillae and about 4 pairs of post-anal ones.

Several worms were found which, on the basis of differences in measurements of the several parts of the digestive tract, appear to be distinct. These measurements are given in Table III. The worms are small compared to *Contracaecum macrozoarcium* and they may be stages in the development of this species, since one larval form with boring tooth on the lip, and an immature male and female specimen,



Text Figure D. *Contracaecum macrozoarcium* sp. nov. 1, 2 Posterior and anterior end of female. 3 Posterior end of male showing spicules. 4 Digestive system: Oe, oesophagus; V, ventriculus; A, appendix; I, intestine; C, intestinal caecum.

TABLE III. COMPARATIVE MEASUREMENTS OF INTESTINAL FORMS OF *Contracaecum* IN *Macrozoarces americanus*

Structure	<i>C. macrozoarcium</i>		<i>Contracaecum</i> sp.		<i>Contracaecum</i> sp.
	Male	Female	Immature	Larval	
No. of Worms	4	6	1	1	1
Length	15-28 mm.	26-45	12	20	10
Width	0.25-0.70	0.50-1.30	0.27	0.31	0.25
Oesophagus	5.30-6.30		2.20	2.40	1.40
Ventriculus	0.14-0.16 x 0.24-0.26		0.20	0.19	0.13
Appendix	1.05-1.12		0.84	0.18	0.63
Caecum	1.40-1.58		0.71	0.78	0.68

are represented in the series. All have the characteristic spiny tip and the lips show the same arrangement of the latero-ventral structures with the interlocking lobes. The writer is uncertain whether or not any taxonomic value can be given to the measurements of the other structures of these worms. The extreme variability of the caecum, as mentioned previously, certainly eliminates measurement of this structure as a diagnostic character. However, it may be summarized that the sexually mature ascaroids described here as *Contracaecum macrozoarcium* differ from other forms in each or all of the following respects: (1) both the caecum and the appendix measure one mm. or more in length, but are not necessarily equal in size, (2) the ventriculus is sub-globular, and (3) male spicules are sub-equal.

4. ACANTHOCEPHALA

Echinorhynchus gadi Zoega, 1776 (Plate VII)

Echinorhynchus gadi is a common parasite of marine fishes of the North Atlantic. Linton (1933) points out that this species has been recorded, either under the name *E. gadi* or its synonym, *E. acus* (Rudolphi) from at least 54 species of fishes from the Woods Hole region. In the large list of hosts he included the ocean pout, *Macrozoarces americanus*. He showed, also, that although the worm has been found in many teleosts, "the specific hosts in which it occurs frequently and in considerable numbers are limited to perhaps ten or twelve." *M. americanus* was not included in this latter list, perhaps because only a few specimens were examined. In the present studies, a large number of ocean pout from several areas along the North Atlantic were examined for their internal parasites. The incidence

of infection is very high and the number of *E. gadi* found was always large. One specimen examined by the writer yielded over 100 of these spiny-headed worms. Linton (1933) recorded a total of 74 from six specimens examined in April.

The generic characters for *Echinorhynchus* were defined by Van Cleave (1919). In 1925 he called attention to the great diversity of form and size in *E. gadi*. Linton (1933) showed, following studies on many specimens taken at random from different hosts, that the variations may extend "to details of structure, such as relative lengths of proboscis, receptacle, lemnisci, number of vertical rows of hooks on the proboscis, number of hooks in a row, and in some degree, to the size of the hooks." To these variations should be added body color, which Linton (1889, 1901) had noted in his earlier descriptions of this parasite under the name *E. acus*. The color of these worms may be ivory, red or orange. Among our specimens white and red were the only colors noted. Both types may occur in the same host, or each color variety may be found in different fish. The cause of this color variation is not known but is probably due to exogenous factors associated with the saprozoic habits of these organisms.

In the ocean pout examined in this survey both immature and mature worms were found. They measure from 10 to 50 mm. or more in length. Mature gravid females usually measure from 20 to 50 mm., while those under 20 mm. are either males or immature individuals. The worms contract and become strongly coiled when placed in preserving fluid. The measurements for the various structures of the parasite vary considerably but are within the range of variation established for these highly plastic organisms. Van Cleave (1925) believed that the variability in body form and size may be influenced by the host species parasitized. This may be so, but the same variation may occur within the same host.

The proboscis measures about one mm. in length in both sexes. The proboscis sheath is slightly longer. The hooks are alternate in arrangement, restricted to the proboscis. There are from 10 to 12 longitudinal rows of these stout recurved hooks, with from 12 to 14 to each row. Except for the basal hooks, which are smaller, they are uniform in size. The neck is short and is free of hooks. The lemnisci extend up to or slightly beyond the posterior level of the proboscis receptacle. The males have well developed copulatory bursa. The gravid females have many embryos in the body cavity which measure

on the average about 80 microns in length and about 10 microns in width.

Echinorhynchus gadi has also been reported from other Zoarcidae. Nicoll (1907) reported the parasite from *Zoarces viviparus* from the British coast under the synonym *E. acus*, and Markowski (1939) recorded it under its correct name from the same host from the Baltic.

SUMMARY

The helminthic parasites of the ocean pout (*Macrozoarces americanus*) consist of the following forms. (a) Trematoda: metacercariae of *Cryptocotyle lingua* found in the skin and fins; metacercarial forms found in the flesh which may or may not be the same. (b) Cestoda: *Bothrimonus intermedius* Cooper from the intestine. (c) Nematoda: *Porrocaecum decipiens* (?) (Krabbe) encapsulated in the flesh and *Contracaecum macrozoarcium* sp. nov. from the intestine. (d) Acanthocephala: *Echinorhynchus gadi* Zoega from the intestine. All the forms listed above, with the exception of the tapeworm, were recovered in the present survey. Insofar as is known, *Macrozoarces americanus* is a new host record for *Cryptocotyle lingua* and *Porrocaecum decipiens* (?). These two parasites and the metacercarial form found in the flesh are important economically since they might affect the marketability and edibility of the fish. *Cryptocotyle lingua* is a potential human parasite.

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III. *PLATYBDELLA BUCCALIS*, SP. NOV., AN ICHTHYOBDELLID LEECH FROM THE MOUTH

The genus *Platybdella* was defined by Malm (1863) as follows:

Corpus modice depressum, longiusculum, ante medium constrictione distincta, diaphanum, non in globulum se involvens. Acetabulum oris evidenter discretum. Acetabulum anale oblique affixum, valde discretum. Annuli parum perspicui.

However, it has been determined by Leigh-Sharpe (1916, 1933), Johansson (1929) and Herter (1936) that the genus *Platybdella* as defined above included forms which have since been allocated to other genera.

The leeches found in the ocean pout are platybdellid forms as defined by these later investigators and belong to a group partially characterized by the presence of four eye spots. A comparison of these related forms shows that *P. buccalis* is different in certain respects and is considered a new species for the reasons which are given below.

Platybdella buccalis sp. nov.

(Plate VIII)

These ichthyobdellid leeches were found in the mouth of a single specimen of *Macrozoarces americanus*. They are pinkish in color; body cylindrical or only slightly flattened. Four worms were found measuring 15, 18, 23, and 35 mm. in length. Superficially the body appears smooth, but on closer examination many fine segmentation markings are evident, the exact number of which could not be determined. The primary annuli are deeper than the secondary ones. The anterior sucker is cupiliform and slightly indented on the dorsal border. It measures about 0.5 mm. in width or slightly narrower than the body proper in this region. Four eye spots, semilunar in shape and brownish in color, are present on the dorsal surface of this sucker.

They are closer together on the vertical axis than on the horizontal. There is no sharp demarcation between the anterior sucker and the rest of the body. Similarly, no sharp distinction can be made between the preclitellar, clitellar and abdominal regions of the body, although these regions can be established by careful examination. The body is narrow at the anterior end, widens slightly throughout the extent of the abdomen and then narrows again at the posterior end. The posterior end is not as wide as the region just behind the anterior sucker. The posterior sucker is terminal, comparatively large, also cupiliform, with its border entirely round and smooth. It is sharply separated from the body and measures from 1 to 1.5 mm. in diameter.

The details of the internal organ systems were not determined. The pharynx is provided with a protrusible proboscis, which is one of the distinguishing characters of the order Rhynchobdellae to which these leeches belong. The anal opening lies a short distance anterior to the region where the body and the posterior sucker join. The region around the anal opening is surrounded by numerous large cocoon gland cells which contain granules (secretory?) that stain deeply with para-carmine. According to Leigh-Sharpe (1916) and others, the glands extend from the end of the clitellum to the anus, forming a continuous layer underneath the subdermal muscle. The efferent ducts open to the surface at the region of the clitellum. They "do not, however, run forward independently one from another without arrangement, but are collected into close bundles which, as well in number as in position, are, in most cases, constant in the same species." Although the reproductive glands could be seen, their number and arrangement, as well as the positions of the external openings of their ducts, were not determined.

Platybdella buccalis is characterized, then, as follows. Anterior sucker smaller than posterior sucker, slightly smaller than the body in the anterior region; body more or less smooth, annulations not distinct, no special markings, excrescence, respiratory vesicles or other structures visible; color pinkish; preclitellar, clitellar and abdomen not especially distinct from one another; posterior sucker about twice the width of the anterior sucker, terminal, sharply separated from the body proper; pharynx with a short protrusible proboscis; anus a short distance from the posterior end of the body, surrounded by large gland cells.

Although several species of *Platybdella* were described by Malm

(1863), it has since been shown by the investigators cited above that the forms which rightfully belong to this genus could be reduced to two species: *P. anarrichae* and *P. quadrioculata*. However, the former is characterized by the absence of eyes. It is commonly found on *Anarrhichas lupus*, and Herter (1936) reported it from gills of *Lycodes pallidus* (Family Zoarcidae) (see also Moore, 1898). *Platybdella quadrioculata* occurs on *Labrus maculatus*, and insofar as is known, it has never been rediscovered since it was originally reported by Malm. According to this investigator this leech is characterized as follows:

Ocelli 4, in series duas longitudinales, antrorsum convergentes, dispositi. Corpus unicolor, postice albo-punctatum. Acetabulum anale fere duplo latius quam acet. oris et 2/3 latitudinis mediae abdominis; concolor.

In some respects *P. buccalis* fits this description, but so do other species which he described and which have since been relegated to other genera (e. g., *P. scorpii* is a synonym of *Janusion scorpii* of Leigh-Sharpe, 1933). In comparing figures, *P. quadrioculata* differs from *P. buccalis* as follows: (1) in general appearance of the body; in *P. quadrioculata* the body is narrow at the anterior end and gradually widens towards the posterior extremity; (2) the oral sucker is more sharply demarcated from the body, and the eye spots are differently spaced; and (3) presence of the white spots. However, again by inspection, the main distinction is based on the size, shape and placement of the anterior and posterior suckers.

A species was described by Moore (1938) from the gill region of *Trematomus hansonii* as *Platybdella levigata* (Harding) (= *Cryobdella levigata*, Harding, 1922). However, this form differs from both *P. quadrioculata* and *P. buccalis* in that the caudal sucker has "a very finely serrated margin of about 160 teeth, the peripheral terminations of as many delicate radiating muscle bands, which are crossed by numerous circular and reticular bands." Other features peculiar to *P. levigata* are as follows: specimens have posterior suckers reversed, i. e., sharply bent dorsad; nuchal constriction deep; primary annuli are much deeper than secondary annuli. However, the last mentioned is also a character of *P. buccalis*.

Abranchus (= *Platybdella*) *sexoculatus* (Malm, 1863) was reported by Johansson (1929) as occurring on *Zoarcetes viviparus*. As the specific name indicates, the leech possesses six eyes.

SUMMARY

Platybdella buccalis sp. nov., an ichthyobdellid leech from the mouth of an ocean pout (*Macrozoarces americanus*), is described and compared with *P. quadrioculata* Malm (1863) and other related species.

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IV. ON A FIBRO-EPITHELIAL GROWTH ON THE SNOUT

(Plates X A, B)

Neoplastic growths in fishes are not uncommon. For a partial review of the literature the reader is referred to the reports of Schamberg and Lucké (1922), Lucké (1940) and Lucké and Schlumberger (1942). Nigrelli (1938) has outlined the possible causes for fish tumors and hyperplasia.

Certain growths are peculiar to fishes, but many of them are similar to neoplasms found in warm-blooded vertebrates. In general they are usually slow growing and benign; a few have invasive characteristics but rarely are they capable of true metastases. Although any part of the body may be involved in these growths, the skin seems to be most commonly affected. Certain of these skin growths are predominantly epithelial in character, while others are chiefly fibrous or composed of cellular elements other than those derived from the epithelium.

The present contribution deals with a fibro-epithelial growth in which the fibrous tissues predominate.

Gross Description. The growth is reddish and rugose in appearance, but some parts are more or less smooth. There is a slight similarity to certain papillary growths found in other vertebrates. It is spongy in texture and extends from the interorbital region, at the level of the middle of the eyes, to a little beyond and overhanging the dorsal border of the maxillary. The conjunctiva of the anterior surface of the left eye is slightly involved. The denser part of the growth is found on the middle of the snout, overgrowing the external nares. The neoplasm extends laterally on both sides to the suborbital regions. The dorsal and posterior parts of the growth are black, superficially resembling a melanosis.

Histological Description. Microscopically the growth is fibro-epithelial in character, in some respects not unlike the fibro-epithelial growths described by Smith and Coates (1938) on the marine turtle, *Chelonia mydas*. The epithelium varies in thickness from two or three to several layers of cells. Keratin formation is not present. Prickle cells showing intercellular bridges are evident but not especially predominant. The cellular elements, including the mucus cells and those of the sensory organs in the epithelium appear normal in structure, arrangement and distribution. There is no evidence of cytoplasmic or intranuclear inclusion bodies in cells stained for this purpose.

The major portion of the growth consists mainly of intermingling bands of fibrous tissue of varying density. In most regions of the growth the two areas, epithelial and fibrous, are distinctly separated from one another by the corial tissue elements or by an especially thickened band of fibrous tissue as shown in Plate X A. This figure also shows the variation seen in the thickness of the epithelial part of the growth together with the arrangement and distribution of the corial melanophores. Occasionally, the corial elements of this growth show invasive tendencies as seen in Plate X B. Here the neat pattern of the epithelial cells is no longer present. The corial cells, together with the melanophores, infiltrate among the epithelial elements, penetrating the basement membrane and eventually destroying and replacing these cells. A certain amount of infiltration also occurs among the muscle fibers; some of the latter are hyalin in appearance. Many of these features have also been described in the melanomas in *Platyopocilus maculatus*-*Xiphophorus hellerii* hybrids by Gordon and Smith (1938).

The blood supply is not especially rich. Certain sections show a delicate network of vessels, the walls of which vary as to thickness. No round cells or other special elements associated with an inflammatory reaction were present.

Discussion. It is evident from the above description that the corium is the primary seat of the fibrous part of the growth found on the ocean pout. It is further evident that the cellular elements arising from this region have invasive characteristics. A somewhat similar condition was also noted by Nigrelli and Gordon (1944) for a melanotic tumor on the skin of a silverside (*Menidia*).

The causative factors responsible for this growth were not determined. It is the opinion of the writer that the neoplasm was in all probability due to trauma. This laboratory has several records (Nigrelli, 1938, 1943), the details of which are as yet unpublished, that certain neoplasms appearing in the head and snout of fishes kept in captivity may be induced by injury resulting from hitting the walls of aquaria.

However, the possibility that the fibro-epithelial growth may be due, either directly or indirectly, to one of the several parasites recorded from the skin and flesh of the ocean pout cannot be excluded. Both protozoan and helminthic forms are of frequent occurrence. It is of interest, however, that copepoda have not been found on this fish. Since they have been recorded from a related host species (*Clavella pinguis* on *Lycopodes frigidus*) by Wilson (1932), it is highly probable that similar crustacean parasites may be found on ocean pout (*Macrozoarces americanus*), but as yet they have not come to our attention.

The host response to the various parasites occurring on the skin or in the flesh of the ocean pout is often manifest by the elaboration of fibrous tissues in the attempts to wall off the invading organisms. This reaction of the host to foreign agents is quite evident at times throughout the body of the fish. Beside metacercarial cysts, numerous bodies, some fatty in nature and others composed of granular debris, in all probability the remains of parasites and host cells, are frequently present and always surrounded with a capsule of fibrous tissue. Therefore, it is altogether possible that any of these agents may have provided the stimulus for the fibro-epithelial growth described above.

SUMMARY

A fibro-epithelial growth, predominantly fibrous, from the snout of an ocean pout (*Macrozoarces americanus*), is described and the probable causes of its growth are discussed.

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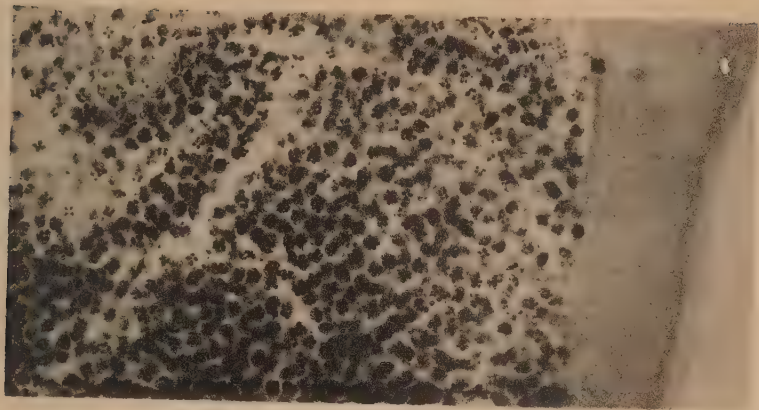
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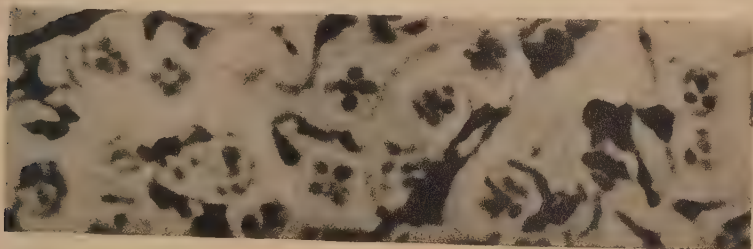
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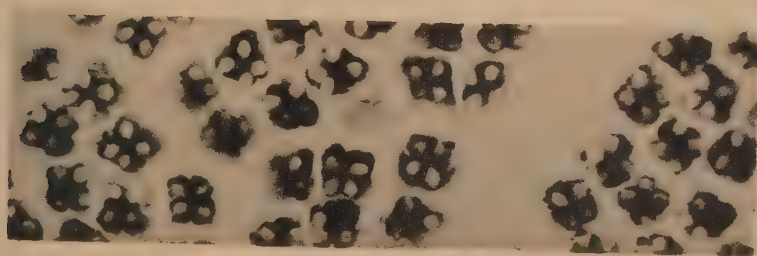
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A

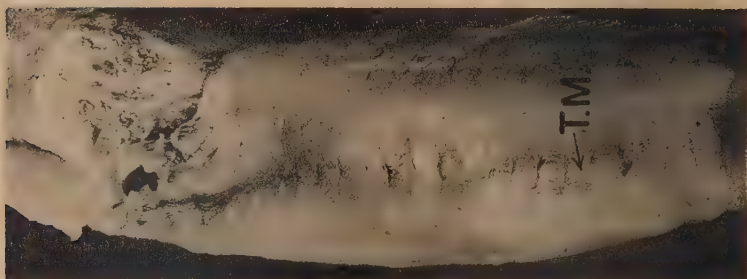


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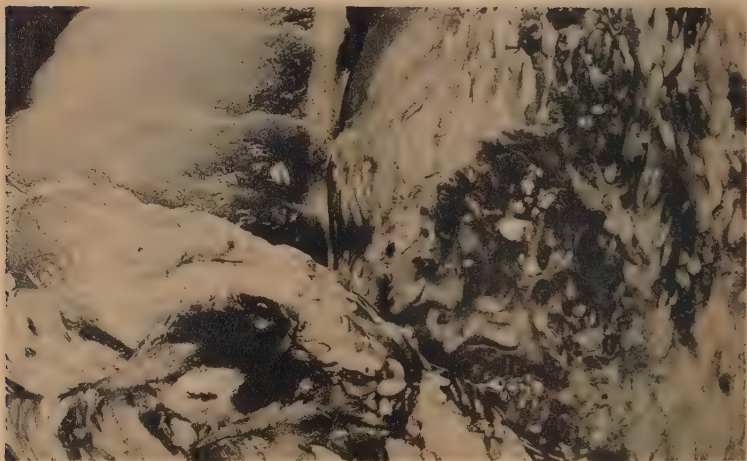


C

Plate I. *Chloromyxum clupei* Hahn. A. Photo-micrograph of section through a muscle bundle showing organisms in stages of sporogony. Iron-haematoxylin. About 600X. B. Smear made directly from nodule showing immature spores with capsulogenous and sporoplasmic nuclei. Iron-haematoxylin. About 900X. C. Stained smear showing typical *Chloromyxum* spores with four polar capsules at the anterior end. Iron-haematoxylin. About 1200X.



A



B

Plate II. *Plistophora macrozoarcidis* sp. nov. (Photographs by S. C. Dunton, New York Zoological Society) A. Photograph of fillet of ocean pout (*Macrozoarces americanus*) showing typical lesions resulting from infection with the microsporidian *Plistophora macrozoarcidis*. Note the minute trophozoitic masses (T.M.) lying along the long axis of the muscle bundles. These masses contain developing schizonts. Immature spores and pansporoblasts may be found in the larger lesions. Reduced $\frac{1}{2}$. B. Enlargement of lesion shown above. It is in the dark granular masses seen in this picture that the mature spores are found. About 2X.

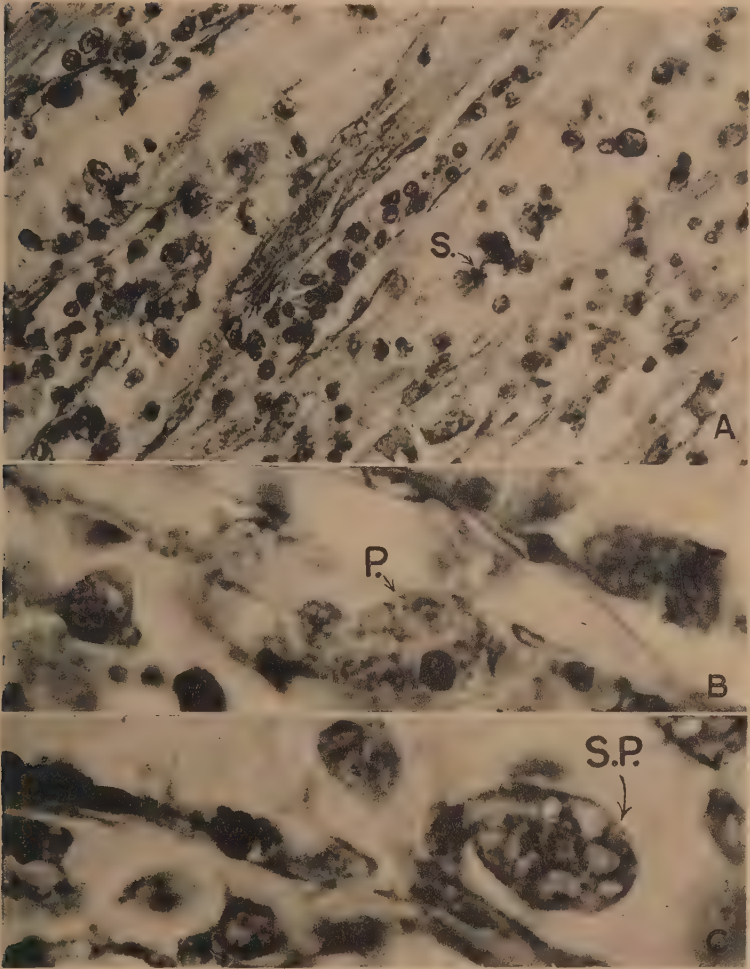
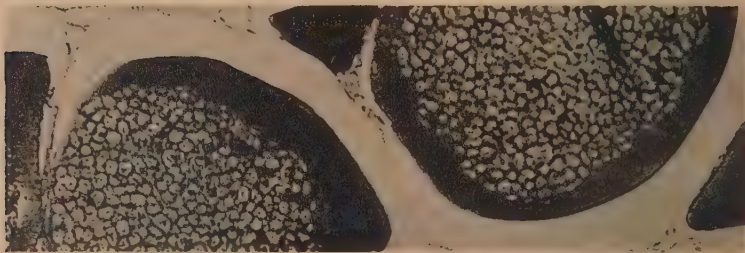


Plate III. *Plistophora macrozoarcidis* sp. nov. (Photographs by S. C. Dunton, New York Zoological Society) A. Schizonts in various stages of development. The cell in "S" is dividing. Delafield's haematoxylin-eosin. About 1500X. B. Pansporoblasts; many of them in the uninucleate stage. Note the cell marked "P". Delafield's haematoxylin-eosin. About 800X. C. Pansporoblasts in the process of sporogony. Some cells have two and others four sporoblasts in the process of being transformed into spores. Note cells marked "S.P." Delafield's haematoxylin-eosin. About 1500X.

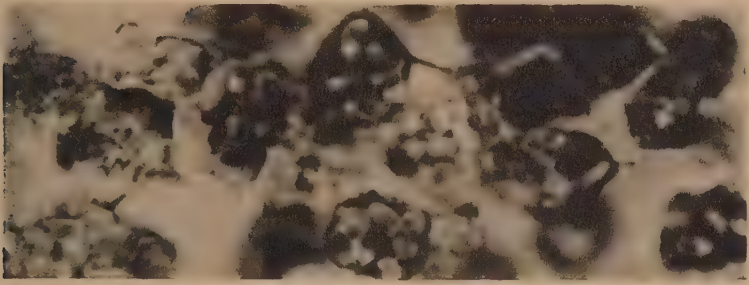


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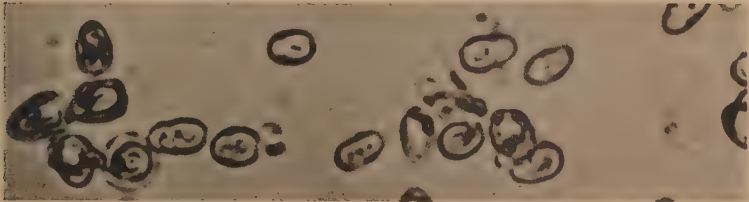


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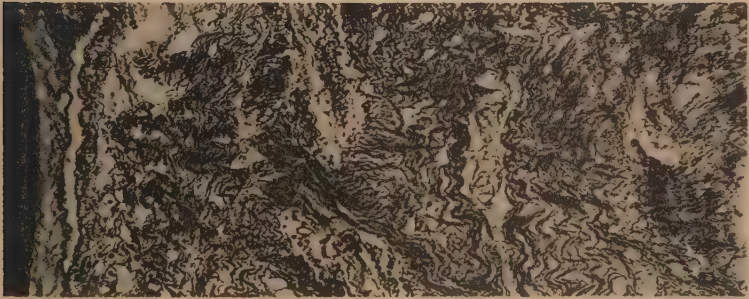
Plate IV. *Plistophora macrozoarcidis* sp. nov. (Photographs by S. C. Dunton, New York Zoological Society) A. Cross section of infected muscle bundles of ocean pout showing "cysts" containing immature spores. Each round body represents a cyst similar to that represented in Text Figure A, 8. Note the hyalin nature of the muscle fibers. These fibers, however, are still intact. Harris' haematoxylin-eosin. About 500X. B. Pansporoblasts in late stage of sporogony. The spores are mature and can be induced to release their polar filaments at this stage. Note the extent of the degeneration of the muscle tissue. Mallory's triple stain. About 500X.



A



B



C

Plate V. *Plistophora macrozoarcidis* sp. nov. (Photographs by S. C. Dunton, New York Zoological Society) A. Mature pansporoblasts dividing. The significance of this division is not known. Some of these spores are released and free among the tissue debris and pansporoblasts. Also among these elements may be found uninucleate cells typical of the schizonts shown in Figure 3. There is some evidence that auto-infection may take place. Delafield's haematoxylin-eosin. About 800X. B. Fresh, unstained spores. Note the variation in size and form. About 1200X. C. Mallory's stained section showing the extent of the development of connective tissue around the developing microsporidians. About 500X.

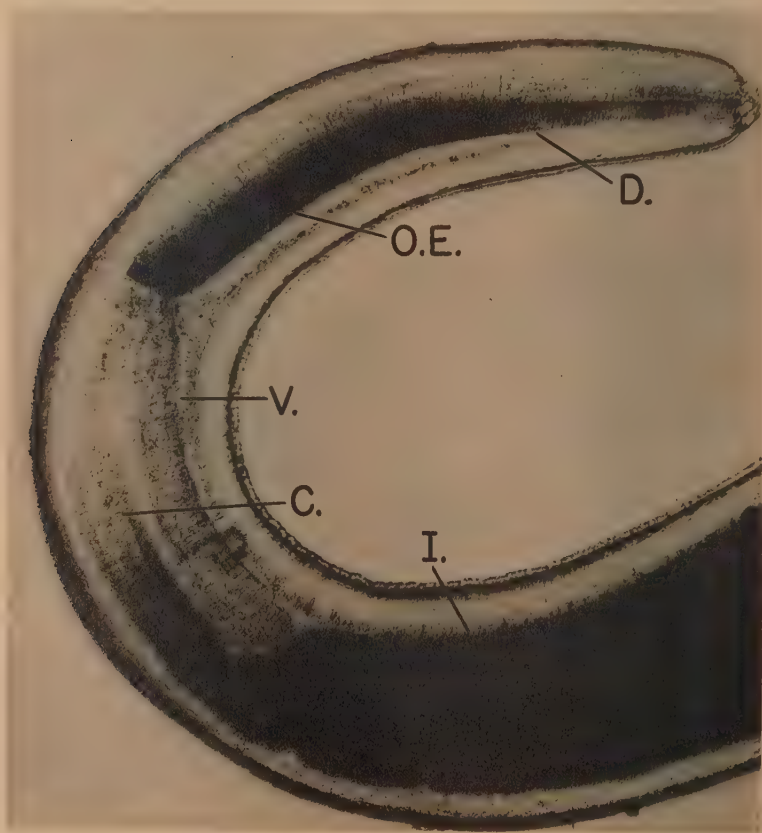


Plate VI. *Porrocaccum decipiens* (?). *Oe*, oesophagus; *D*, duct of excretory gland; *V*., ventriculus; *C*, intestinal caeca; *I*, intestine. About 20X.



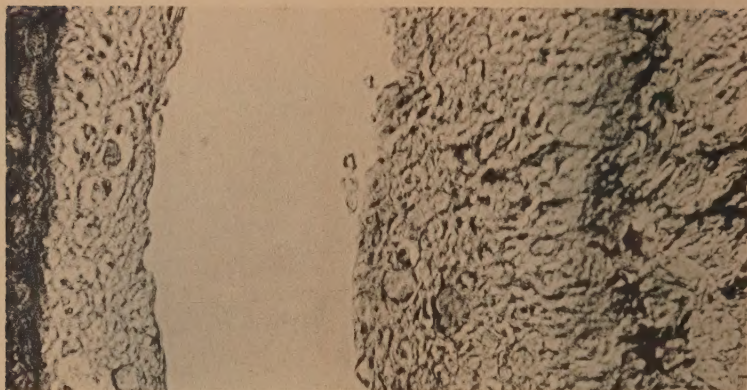
Plate VII. *Echinorhynchus gadi* Zoega. Acanthocephalan from the intestine of *Macrozoarces americanus*. Proboscis fully extruded. Stained with Paracarmin. About 75X.



Plate VIII. (Photographs by S. C. Dunton, New York Zoological Society) A. *Platybdella buccalis* sp. nov. 6X. B. Anterior end enlarged to show details of ocelli. Note arrangement of eye spots, oral sucker and primary annuli. 9X.



Plate IX. (Photograph by S. C. Dunton, New York Zoological Society)
Photograph of the head of an ocean pout, *Macrozoarces americanus*, showing fibro-epithelial growth. About natural size.



A



B

Plate X. A. Photomicrograph of a Mallory's stained section of fibro-epithelial growth. Note the variation in thickness of the epithelium, the corial melanophores and the exceptionally thickened band of fibrous tissue. About 950X. B. Section showing the corial elements invading the epithelium. Harris' haematoxylin-eosin. About 950X.